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Alberta
DEPARTMENT OF HOUSING

Innovative Housing Grants Program

THE DEVELOPMENT OF A MOVEABLE WINDOW INSULATING CURTAIN

By Michael Kerfoot and Bernie Lawrence of Sunergy Systems Ltd.

Introduction

In today's super insulated houses heat loss through windows can represent about one-third of the total heat loss. Significant energy savings can be achieved by closing off the window during the night with a movable insulating curtain.

Research

The report discusses the existing window insulating systems, develops criteria for a window insulating system, researches a wide variety of fabrics and other materials for movable insulating curtains and develops a method to measure the R values of a large number of materials for insulating curtains. Based on their research, the authors designed and developed a movable insulating curtain called "Sunseal".

Movable Insulating Curtain

The curtain consists of two layers of ARN (aluminized reflective nylon) fabric on either two-or-three-inch diameter rollers

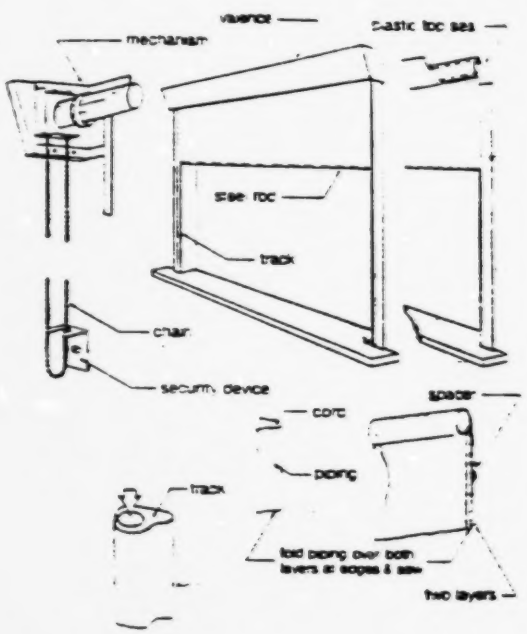

Figure 1. A Movable Insulating Curtain

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with an air space between the two layers. It has a draped polyethene top seal and a one quarter inch diameter metal rod to weigh the curtain down when fully extended (which also provides a bottom seal).

Edge seals are achieved by a cord sewn into the two edges of the blind which slide in a custom extruded slotted tubular PVC track of one-half inch width. The curtain is controlled manually by means of continuous loop bead chain which can be secured at any point, fixing the curtain at the desired height. For those preferring automatic operation, a tubular motor is available with a thermostat or timer control.

Conclusion

The movable insulating curtain can reduce heat loss through windows by more than 50 per cent when compared to standard double glazing.
Insulating curtain kits containing materials and hardware to fabricate and install the complete curtain are being sold by Sunergy Systems Ltd.

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DEVELOPMENT OF A MOVABLE INSULATING CURTAIN

Alberta

DEVELOPMENT OF A MOVABLE INSULATING CURTAIN

September 1983

Prepared By:

MICHAEL KERFOOT AND BERNIE LAWRENCE

SUNERGY SYSTEMS LTD.

The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of the Alberta Department of Housing.

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FOREWORD

This study was made possible with funding provided by the Innovative Housing Grants Program of the Alberta Department of Housing. Originally conceived in 1978, the Program is intended to encourage, sponsor, and assist research and development in the fields of housing, site and subdivision design, energy conservation, site servicing and urban development. Generally, the aims of research funded by the Innovative Housing Grants Program are to reduce housing costs, increase the supply of appropriate housing or improve the utility or performance of dwelling units or subdivisions.

The main purpose of funding these studies is to examine the current issues in the field of housing and to develop innovations which offer improvements. Comments and suggestions regarding the information contained in these reports are welcome.

Innovative ideas come from a wide variety of applicants such as builders, developers, consulting firms, industry associations, municipal governments, educational institutions, non-profit groups and individuals. As the type of project and level of resources vary from applicant to applicant, the resulting documents are also varied.

Where possible the Department encourages the dissemination of study results under a standard cover and in a uniform format. This study, Development of a Movable Insulating Curtain, was completed in April 1982 and subsequently released under a different cover.

Please send comments and suggestions or requests for further information to:

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September 1983

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We are also greatly indebted to Winnie Robertson, of Carstairs, who allowed us to convert her home into a laboratory for several months. And to all the other homeowners whose living rooms we have disrupted.

We would like to thank Patty Malone, of the head office of Alcan, for his assistance during our aluminum studies. We are also grateful for the information offered by other technical staff at a range of manufacturing firms.

The National Research Council staff at both the Ottawa and especially the Saskatoon branches were very helpful in refining our test procedure and must receive our gratitude.

And lastly, to Glen Nelson of Clivus Multrum Northern Rockies, in Whitefish, Montana, must go our grateful thanks for his range of knowledge and critical feedback on many of our activities.

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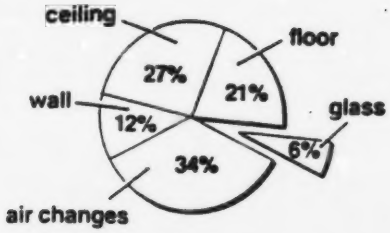
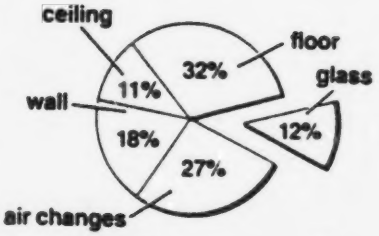
1. INTRODUCTION

Energy efficiency has become something of a catch-word in most discussions of energy - and with good merit. Conserving energy is the simplest, least expensive and most achievable way of reducing energy consumption. Much effort has been directed towards increasing the energy efficiency of buildings; increased insulation, tight weather-stripping and sealing, continuous vapour barriers, double-glazed south-facing windows and incorporation of thermal mass have helped adapt housing designs to the unique Canadian climate.

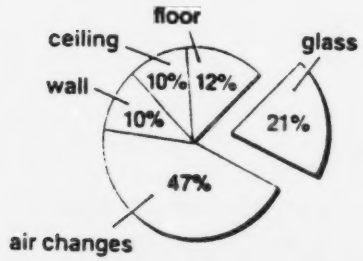
A major problem, though, continues to plague the designers, builders and owners of homes with large expanses of glass. As the energy efficiency of a building increases, the percentage of heat lost through glazed areas does the same. The following diagram (Figure 1) illustrates that, although methods have been developed to reduce heat loss through the incorporation of additional insulation and tighter vapour barrier, glazed areas represent an increasing proportion of heat loss. Indeed, five to ten per cent of the national energy consumption can be attributed to heat loss through windows.



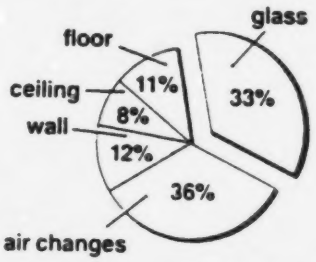
House A (1858) has no insulation. The windows are small and equivalent to only 9% of the floor area (121 square feet). The house is full of cracks and it has an open fireplace so four air changes per hour are common. Even though the windows in this house are single glazed, they account for only 6% of the heat losses.



House B (1928) is similar to House A except that 2 inches of insulation have been added to the attic and tighter construction has reduced the air changes to two per hour. A few windows have also been enlarged to make a total glass area of 145 square feet or 11% of the floor area. Still using single glass, the windows in this home lose through them 12% of the house's heat.



House C (1958) was built in the post-World War II era. Glass had become much lower in cost and was available in large double-glazed sheets. The window areas of this home are 19% of the floor area or a total of 242 square feet. Three inches of insulation were used in the walls, 6 inches in the ceiling, and 3 inches in the floor, and air changes have been reduced to 1.5 per hour. Even though all the glass in this house is double glazed, the percentage of heat lost through the windows has jumped to 21% of the total losses. The window heat losses here are similar to losses in houses built 50 years earlier, when single glazing was used, since the reduction caused by double glazing has been offset by the additional window area.



House D (1978) was built during the diminishing fuel reserves era of the late 1970s. With the housing market getting serious about energy conservation, the air changes have now been reduced to 0.75 per hour. Six inches of insulation are used in the floor, 12 inches in the ceiling, and 5 inches in the walls. The 242 square feet of double-glazed glass—the same as in House C—causes 33% of this home's heat to be lost through windows.

FIG. 1

FOUR HOMES OVER THE LAST 120 YEARS (REF. 4)

Today's generation of super-insulated houses focuses on this problem. A typical energy efficient home with double-stud walls achieves an R-value of close to 40 in the walls, 60-70 in the ceiling; a double-glazed window has an R-value of 1.8 one-twenty-fifth that of the wall! One solution is to limit the number and size of windows on a home to the minimum requirements. Then, increase the insulative value of the glass by adding extra panes - to triple and even quadruple glazing. Of course, additional glazing drastically reduces solar gain due to glazing reflection and absorption losses.

While this is an adequate response to the heat loss problem, it is hardly adequate to meet other needs. In spite of rising energy costs, a recent study has shown that the percentage of glazed areas on homes has been steadily increasing since 1975. This is a result of the ability of windows to meet a variety of homeowner needs. Natural daylighting adds an important physical and psychological benefit to a home. Large glazed areas are requisite to grow ornamental, as well as food-producing plants indoors, a consideration of increasing impact for many homeowners. Windows can be used for ventilation, for viewing, as emergency egress (i.e., in case of fire), or ingress (when you've left your house keys in your other pants' pocket!). And of crucial concern for designers of passive solar

buildings, windows allow significant incoming solar radiation to reduce the heating requirements of the home.

Given that windows represent severe heat losses but recognizing that they also offer so many benefits to a home, how can this dilemna be resolved?

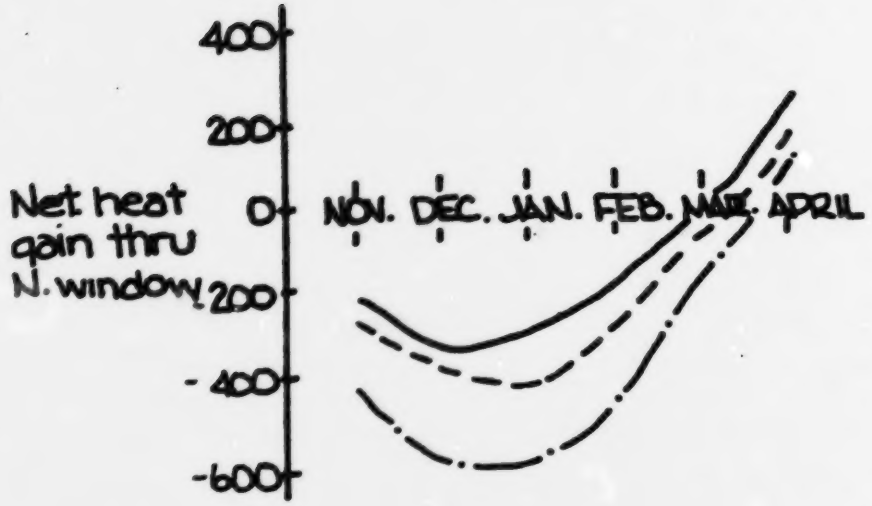
An excellent resolution is movable window insulation; that is, insulation that covers the window to reduce heat loss but is easily removed when daylighting, viewing and/or solar gain is available. As the graphs in Figure 2 show, a double-glazed window with a minimum of night insulation represents a dramatic improvement in the net heat flux of windows through the entire heating season.

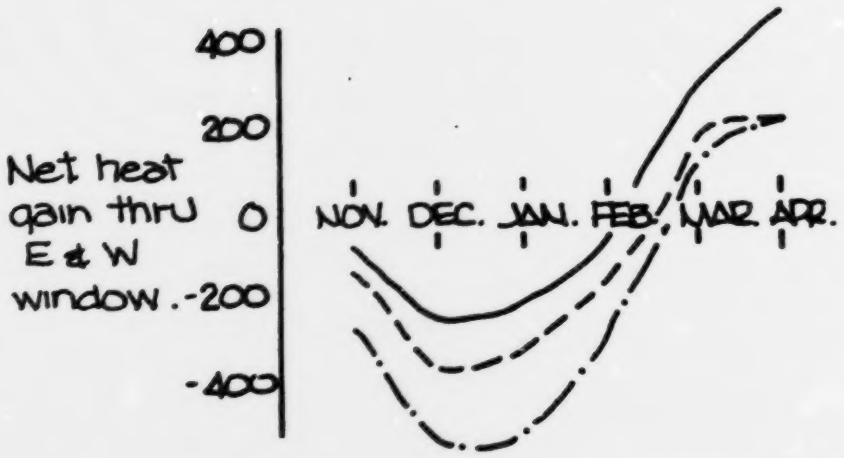
Studies by Los Alamos Scientific Laboratories indicate that the effectiveness of a water Trombe wall for space heating in Edmonton can be almost doubled with the addition of an R-10 night insulation system.

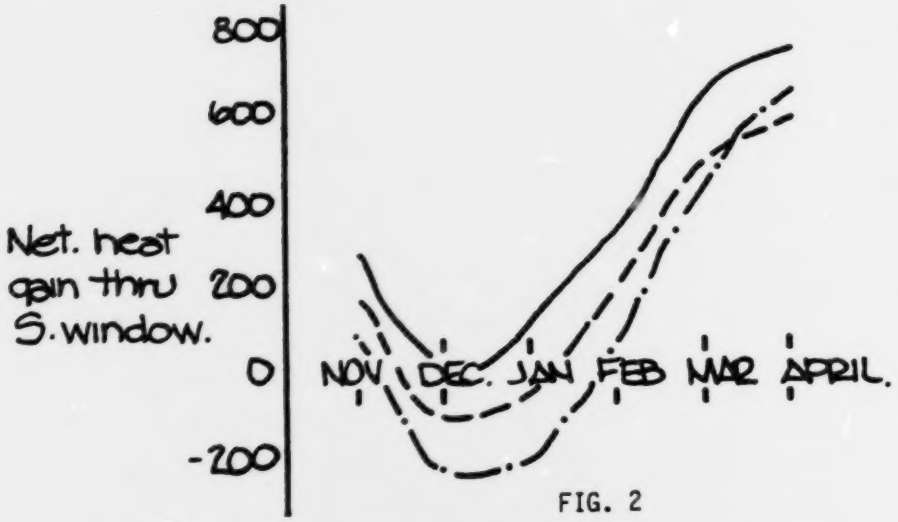
As Bill Shurcliff, long time solar pioneer and writer, points out, "The wolf isn't at the door; he's at the window!

DESIGN CRITERIA FOR MOVABLE WINDOW INSULATION (M.W.I.)

Having identified a need both for windows and for movable window insulation, it is useful to establish the goals which the insulating system must meet. The demands placed upon such a system are considerable and a number of parameters can be identified.







Legend:

———Dbl. Glazing W/Night Insulation

– – – – –Tpl. Glazing

—·—·—Dbl. Glazing

Assume:

- U Value of double glazed window = 0.56 BTU $ft^{-2}°F^{-1}hr^{-1}$
- U Value of night insulation = 0.32 BTU $ft^{-2}°F^{-1}hr^{-1}$
- Transmittance of double glazing is 0.75.
- Transmittance of triple glazing is 0.63.
- Night insulation in place 14 hrs, Nov., Dec., Jan., & Feb.; 12 hrs Mar., & Apr.

FIG. 2

SEASONAL WINDOW HEAT FLUX (EDMONTON)

1) Insulating capability of material: Before this characteristic can be assessed, the nature of heat loss must be discussed. The three types of energy flow associated with windows are conductive, convective (including in/exfiltration) and radiative.

Conduction: Conduction is the transfer of energy through a molecular interaction. Air, being such a low density medium, offers a very low conductivity of heat. The creation of air spaces, for example as with multi-glazing, is a common technique of retarding conduction. A maze of trapped air cells is the inherent feature of most common insulation materials. It is these basic principles that are applied in designing m.w.i. systems.

Convection: This topic, as Shurcliff points out, is one "that makes engineers blush. There are complications within complications".

Because of the number of variables associated with this type of heat loss, it would be inappropriate to delve into the subject in great detail in this report. Suffice to say that density-driven air currents, though difficult to trace, are effective transporters of heat. If the window insulating devices can be made adequately airtight to prevent air leakage, a major source of heat loss can be controlled. This, as shall be seen shortly, is not so easy a task.

A number of window insulating options attack the problem of conductive heat loss with vigour and effectiveness. Fewer are as successful with convective heat loss. And many avoid the most fascinating issue of radiation.

Radiation: For the purpose of studying window insulation, we shall limit our discussion of radiation to two major and distinct bands:

i) solar radiation ranges in wavelengths from ultraviolet to near-infra red. (.3 to 3 microns)

ii) far infrared (IR) radiation (3 to 80 microns) is that emitted by all warm objects - that is, all objects above absolute zero.

The accompanying graph (Figure 3) illustrates this variance. Note that a body at room temperature emits radiation which peaks in the spectral range of 10 microns.

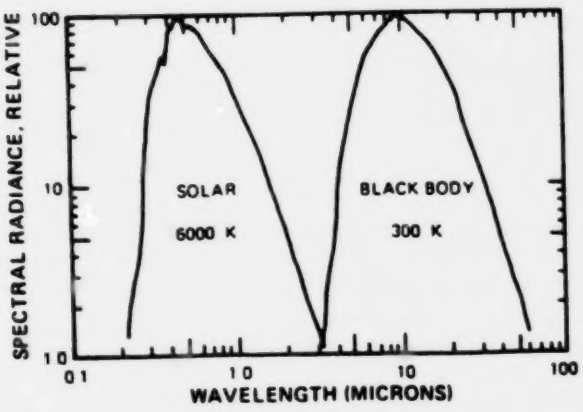


Fig. 3 (Ref. 13)

What is the significance of this range of wavelengths? This is dependent upon the ability of glazing materials to transmit radiation; because the bands are distinct and separate, glazing materials respond to them differently. Glass for instance transmits well through the first band (86 per cent). It is opaque, however, to 98 per cent of the far IR radiation.

These observations can be applied to the topic of heat loss through windows. First, it should be recognized that heat loss in the form of radiation from a warm body to a cooler one can be significant. Hence, the degree of radiant heat flow from objects within a room to dramatically colder surfaces such as windows or the outdoors beyond should be similarly important.

The greenhouse effect, a commonly taught and accepted theory, downplays this significance. As previously noted, glass transmits a large proportion of solar radiation. This radiation is then absorbed by interior surfaces and re-radiated to the glass in the form of long wave IR radiation. Since glass is opaque to this long wave radiation, the heat loss associated with this source is said to be negligible.

However, it should be noted that although glass does absorb most of the outgoing radiation, in doing this it becomes warm. Surfaces emit radiant heat at a rate

proportional to the fourth power of the absolute temperature of the body. Since glass is a high emitter (emittance of .84) it will then re-radiate this heat in both directions - preferentially towards the colder exterior. Therefore, radiant heat loss through glass can indeed be significant!

Fortunately, an inexpensive and readily available material exists which, rather than absorbing and re-radiating this IR radiation, reflects 92-97 per cent of it. This material - aluminum foil - is extremely effective in reducing heat flow.

This excellent insulating capability of aluminum foil can be readily comprehended by studying its reflectance and emittance properties.

1) The heat radiation that is directed towards the foil surface from the warm objects within a room is predominantly reflected. Only about 5 per cent is actually absorbed to raise the temperature of the foil.
2) Since all objects radiate heat and do so in relationship to the temperature surrounding them, considerable heat can be expected to be lost by radiation from an m.w.i. system to a window. However, the emittance of Al foil is so low (.05) that very little heat is actually lost by radiation to the window.

It should be understood that reflectivity and emissivity come into play when the particular surface is bonded by an air space of preferably at least one half-inch. This is important. Heat will still be lost from the foil surface by direct conduction to the air molecules immediately adjacent and these in turn will be removed by convection. However, the resistance of the adjacent air film to convection minimizes this mode of heat transfer.

This theory has been borne out in tests by, for example, Robert Flower of the Rodale Press Design Center. He found that a single glazed window (glass) with a 4 mil polyethylene sheet placed in front achieved an R-value of 1.64 (polyethylene transmits effectively through both near and far IR spectrum). However, when a single sheet of aluminized mylar replaced the polyethylene in front of the window, an R-value of 3.3 was achieved! These tests were later corroborated in our testing facilities. (see pp. 54 - 57)

It appears from this discussion that heat loss through windows can indeed be controlled using a number of materials, either singularly or in combination. The next critical question is: To what degree should this loss be controlled?

Clearly, the higher the insulative capability of a

window insulating device, the less heat will be lost. However, as Figure 4 indicates, the relative merits of increasing the R-value of the insulating device diminishes rapidly beyond a certain point. For example, a window/insulation combination of R5 achieves a theoretical savings of 64 per cent. Doubling the R-value to 10 increases the savings only slightly on a chilly January night, while dramatically increasing the cost, complexity and inconvenience of the insulating device.

Assumptions:

.u-value of double glazing is.56(1)
.curtain is in place for 15 hours
.temperature differential of 70 Fahrenheit degrees

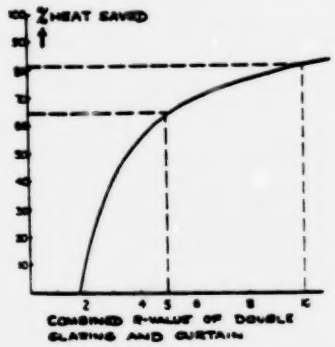


Fig. 4

The basic system should be flexible enough to accommodate a range of insulating levels. For instance, a greenhouse or sunspace may have heat losses controlled to an acceptable level with R2 night insulation. On the other hand, typical living areas would do better with a higher insulation level. The system must allow for this variance without requiring major changes in hardware or installation.

Some words of warning should be issued here. R-values, though useful in terms of comparison, are somewhat misleading when applied to m.w.i. systems. R-values claimed by m.w.i. distributors are seldom reached since they are often theoretical rather than actual R-values. The discrepancies between theory and practice occur because of the following variables:

i) Theoretical R-values assume a uniform place or sheet of insulating material.

ii) They assume perfect edge seals or no edges that would allow passage of air. These edges usually represent major areas of heat loss and subsequent lowering of the insulative capability of the m.w.i. system.

iii) The insulative capability varies with the location of the testing instruments. This variance, as indicated in our tests, can be dramatic.

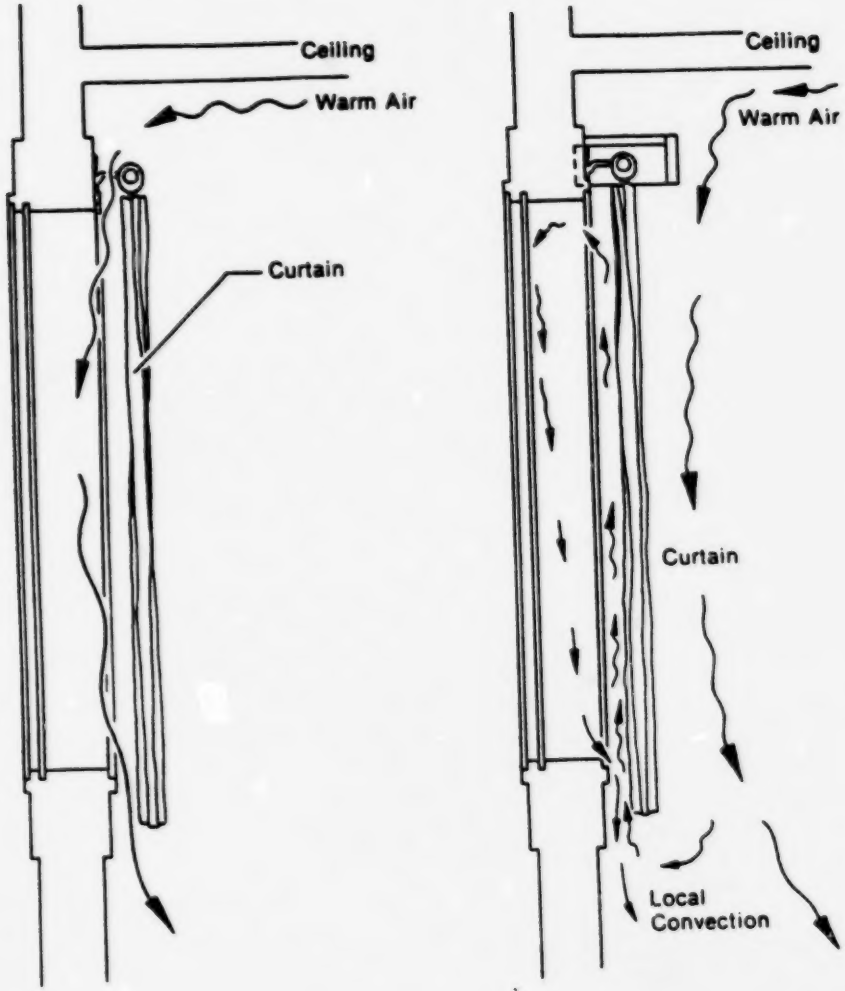
2) Air/vapour permeability: The amount of air allowed to diffuse through the insulating device must be minimized. This improved the insulative capability by reducing convective losses and minimizes condensation problems created by warm, moist interior air coming in contact with the cool glass.

3) Edge Seal: For the same reasons in 2), the amount of

air allowed to flow around the perimeter of the insulating device must be minimized. This, however, turns out to be no small task. "The great problem with moveable insulation is cracks," noted Steve Baer in a presentation at the 1976 Passive Solar Heating and Cooling Conference. "A door, shutter, or curtain is placed in front of a window to stop heat loss. The optimist noted the R-value of the material and predicts success but, in fact,he does not achieve it."

Some would suggest that an insulating device should be expected to suppress air infiltration losses caused by improperly sealed windows. However, this places undue demands on the m.w.i. system. Certainly a caulking gun and a tube of sealant are a more task efficient means of reducing these losses. The insulating device is more than adequately challenged with the task of suppressing indoor convective currents.

Even in a well sealed window, significant heat losses can be incurred with m.w.i. systems that have less-than -tight edge seals. Insidious convective currents can actually INCREASE the heat loss through a window as illustrated in Figure 5. With a gap between glazing and insulation, accompanied by gaps at the top and bottom, a chimney effect can be created. Warm moist air is introduced at the top of the curtain, is chilled by the glass, becomes more dense and falls, pulling more warm air in at the top. This convective loop can negate the benefits of the window insulation.



CONVECTION AT CURTAINED WINDOW

CONVECTION WITH TOP CAP OVER CURTAIN

FIG. 5 (REF. 3)

In our harsh climate the problem is accentuated. In most parts of the U. S. convective leakage can cause some degree of condensation. However, given the extreme temperature differences faced in a Canadian winter, this condensation will take the form of frost. Buildup of frost within the window jam, or on the sill can lead to devastating consequences for the homeowner. This problem is particularly important when dealing with energy efficient houses with few air exchanges and higher humidity levels.

For these reasons, much of our effort has been directed towards developing an effective, reliable, edge seal system.

4) Economic accessibility: The cost of a window insulating system varies dramatically ranging from a few cents a square foot for polyethylene bubble pack, to $40/sq.ft. for high quality insulating shutters. Even within the realm of comparable products, such as insulating curtains, prices range significantly. What kind of limitations should be placed on the cost of an insulating device?

There are a variety of benefits to be derived from the installation of a m.w.i. system. Certainly the savings in heating fuel costs must be considered when justifying the purchase. Shurcliff suggests that any insulating device costing over U.S. $5/sq. ft. is not economically justifiable

(or more generally, 10 times the first year savings of the device). Others suggest a higher 'P', or present worth factor, is more appropriate given the rising costs of conventional energy sources.

To assess the economic justifiability in Alberta, where energy prices are quite low, it is worth determining a P factor for this area. Using the following formula, this can be calculated:

$$y = \frac{i-x}{1+x} \quad \text{and} \quad P = \frac{1-(1+y)^{-N}}{y} \ .$$

where 'y' is the effective interest rate, 'i' is the nominal interest rate and 'x' is the fuel inflation rate and 'N' is the length of the term.

With a daily savings rate of 13 per cent and a fuel inflation rate of twenty per cent (which is conservative), y will equal - .06. Assuming that the insulating device has a lift expectancy of only 10 years, the corresponding P factor is 14.

To ascertain the significance of this in economic terms, the heating costs saved by the insulating device must be determined. Using climatic data for Edmonton, the following heat savings result from the use of an R3.2 night insulation:

Effective Degree Days (over heating season) = 8200
Therefore heat saving = 8200° F-day x 24 hr/day x U-value (difference between double glazing and d.g. + m.w.i.)

=8200 x 24 x .2
=34,560 Btu/sq.ft.

Fuel saved = 34,560 x 1.7 (furnace efficiency factor)
= 58,752 Btu/sq. ft.

Fuel costs savings = 58,752 x $\frac{\$2.50}{10^5}$ (cost of natural gas per therm - 10^6 Btu)

= 15 cents

Therefore, with a P factor of 14, the amount which a homeowner can economically justify spending on a night insulation system is 14 x 15 cents or $2.10 per sq. ft. Remember that this assumes a high interest rate, low-cost fuel (natural gas) and a moderate fuel inflation rate.

When assessing the value of a m.w.i. system, other benefits beyond fuel cost savings must be considered. Insulating curtains, for instance, can be used decoratively within a home, thereby replacing conventional curtains. As well, curtains are installed for the purpose of privacy. And, of course, window insulation increases the perceived human comfort within a room by intercepting the flow of radiant heat from a person's body to the cold night sky.

It is important to note, though, that most decisions made by homeowners are not founded solely upon economics.Who questions the payback time for a hot tub, a trip to Hawaii, or even wallpaper for the bathroom?

Particularly in the case of early adopters of insulating systems, cost has not been a high priority. For these, the goal of self-reliance overrides most other concerns and often financial sacrifices are made to achieve this end.

Also, recognition must be given to the do-it-yourself interest. A large number of thermal shutters and shades have been fabricated, installed and now operated faithfully in many homes because of the initiative of the homeowner. By providing the device in kit form for fabrication and installation by the homeowner, the needs of the owner-builder can be met - and of course costs can be further reduced.

5) Size: For most windows smaller than about four by five feet, a rigid shutter system can usually be bought or built to meet the needs of the owner. For a larger window, though, shutters become awkward to handle, difficult to hide, time-consuming to operate and inconvenient. A curtain is needed to meet the needs of the new generation of solar homes. Glazed areas of up to 20 feet high and 20 to 30 feet wide must be insulated in as few modules as possible.

6) Reliability and Durability: Not only must the device be maintenance-free, but the entire assembly must be able to withstand normal wear and tear caused by daily operation. It must be resistant to the deleterious effects of high humidity, free water, physical abrasion, and ultraviolet radiation.

7) Simplicity in installation and operation: In order for a kit to be made available for owner-installation, the insulating assembly must be simple to install. The ease of operation of the device must also be considered since a bulky, time-consuming or inconvenient insulation system would probably, over time, be avoided.

8) Heat rejection capability: Although the heat gained by large southfacing windows is beneficial during certain seasons, overheating can become a problem at other times. To avoid this, the insulating device must be able to reject the sun's radiation. For this purpose, a curtain lowered from the top would allow the homeowner to see through the lower half of the window while reflecting solar radiation from the upper portion.

The choice of material used in the insulating device should respond to this need. A light-coloured, open weave fabric curtain reduces solar gain by less than 50 per cent. A reflective, aluminized curtain, though, can increase this to 80-90 per cent.

Other opportunities such as privacy and control over the darkening of the room are afforded by the use of insulating shades as well.

9) Applicability to retrofit situations: The insulating assembly must be able to meet the needs not only of new construction but also that of existing homes. The

height and width must be variable and the installation adaptable.

10) Manual and automatatic operation: Although cost considerations encourage the homeowner to manually operate the insulating system, certain situations such as size, accessibility and lifestyle of the owner dictate that the assembly must be amendable to automation.

11) Regional availability and fabrication: Most commercial systems available today are manufactured in the United States. Importing them dramatically increases the cost and, from our experience, is time-consuming and inconvenient. As well, it is important to suit the insulating device to climatic imperatives of the region. For example, horizontal exterior shutters may be very functional in California but are not appropriate to regions experiencing high snowfall.

It is thus important that the system be fabricated and made available regionally.

12) Aesthetic: The insulating device must either be pleasing in itself or allow for simple homowner upgrading of its appearance. Ideally a variety of finishes, colours and textures should be optional to meet various situations.

13) Lightweight: The device must be lightweight in order to facilitate manual operation.

14) Washable: In order to maintain appearance, the material must be easily cleaned.

Having identified the major criteria which an insulating system should meet, it is prudent to note that even a superb system can experience some difficulties. Some window companies will void their guarantee if certain insulating curtains are used. This is typically because of thermal stresses placed on the glass when the curtain is down during sunny periods and the temperature between the insulation and glass increases.

Of greater significance, perhaps, is the possibility of the cold weather breakage of sealed units. R. L. Quirouette, of National Research Council, notes that "this is likely to occur when the shutter is opened in the morning exposing the cold window to the higher indoor temperatures. Under these conditions the glass is subject to a rapid increase in temperature in its central region thereby causing a tension stress at the cold edge of the window....cold weather breakage is known to occur in sealed units without shutters and inside shutters will certainly aggravate the condition".

Thus, there are a number of areas where the interactive effects between insulating systems and the windows themselves remain somewhat hazy. In our inquiries as to

operating problems with systems in the States, we have not had people mention this concern with cold weather breakage. However, such information will be gained primarily through years of actual operational experience and observation in our climate.

ANALYSIS OF EXISTING OPTIONS:

Having established the criteria, we can judge the quality of existing moveable window insulation systems, both owner-built and commercial options. A brief assessment of many of the available systems is presented in Figure 7. A detailed, written assessment follows. Note that the chart evaluates the relative effectiveness of each of the systems to meet the criteria; that is, the systems are judged in comparison with the effectiveness which comparable systems have been able to achieve.

Also, it should be pointed out that, although little attempt has been made to priorize the criteria, many of the requirements of an m.w.i. system are essential. An insulating device could meet all but one of the criteria and still be considered a poor system.

In our assessment, some commercial options have been excluded for various reasons. Skylids, for example, meet a very specific need (skylight insulation) but are not applicable to the broad needs we have defined. Others meet so few of these needs that they have been omitted, eg.,

FIGURE 7 - A

ASSESSMENT OF OWNER BUILT SYSTEMS

	EXTERIOR SHUTTERS	INTERIOR SHUTTERS	POCKET SHUTTERS	QUILTED CURTAINS	MULTI-GLAZING
INSULATIVE CAPABILITY	3	3	3	1	2
AIR/VAPOUR PERMEABILITY	3	3	3	2	3
EDGE SEALS	3	3	3	2	3
COST	2	3	1	3	2
SIZE	1	1	1	2	2
RELIABILITY/ DURABILITY	1	2	3	2	3
SIMPLICITY	1	2	2	2	3
HEAT REJECTION	3	3	3	2	0
ABILITY TO RETROFIT	2	2	0	2	2

0 - 3

VERY POOR - EXCELLENT

FIG. 7 B

ASSESSMENT OF COMMERCIAL OPTIONS

	THERMA FOLD	ROLLADEN TYPE	INSUL SHUTTER	SUN-SAVER	SUN MOVER	SUN-FLAKE	WINDOW WARMER	CURTAIN WALL	QUILTED REF.TYPE	HEAT TRAP	HEAT MIRROR	SUNSEAL
INSULATIVE CAPABILITY	3	1	3	3	1	3	1	3	2	3	2	2
AIR/VAPOR PERMEABILITY	3	1	3	3	1	3	2	3	3	3	3	3
EDGE SEALS	3	1	3	3	1	2	2	1	3	3	3	3
COST	1	1	1	2	1	1	2	2	2	1	?	3
SIZE	1	2	1	1	1	1	1	3	2	2	2	3
RELIABILITY/ DURABILITY	2	2	3	3	3	3	2	2	2	2	?	2
SIMPLICITY	2	2	2	2	2	2	2	2	2	2	3	2
HEAT REJECTION	3	3	2	2	3	3	1	3	1	3	0	3
ABILITY TO RETROFIT	2	2	2	1	1	0	2	3	3	1	2	3

0 - 3
VERY POOR - EXCELLENT

Thermalite, SilliShutters. And lastly, there are some commercial options for which we have not yet received technical information. The field of m.w.i. systems is a dynamic one with new companies and products appearing and dissolving continually. We do feel, however, that we have examined the better known and more successful systems.

As the chart indicates, the existing systems can be divided into two catetgories - owner-built and commercial; The owner-built options include the following: exterior, interior and pocket shutters, homemade quilted curtains and multi-glazing. A close examination of these systems identifies both merits and drawbacks.

a) Exterior Shutters: These shutters are typically composed of a core of rigid foam insulation such as urethane or isocyanurate. They are covered with a protective sheeting and hinged in some manner to the exterior of the building.

They provide good insulative capability, can reject heat and are amendable to retrofit situations.

However, because they are located outside, they must be weatherized against the extremes of the Canadian climate: high winds, heavy snows, ice, extreme temperatures, et. This

task is very difficult, especially with the tendency of larger shutters to warp. The shutters must be made operable from the inside; few homowners will venture outside on a cold winter night to close the shutters. Operating them from the inside creates mechanical complications and damages the air and thermal integrity of the skin of the building. There is a definite limitation on the size of manageable shutters. And lastly, even the owner-built systems are fairly expensive.

b) Interior Shutters: To avoid the problem of weatherizing, some owner-builders prefer shutters on the interior. Such shutters are again typified by a rigid foam insulation core protected and decorated by a facing material. Some, such as Zomeworks' Nightwall, use inexpensive beadboard secured to the window area using magnetic clips. They require manual operation to secure the sheet in place each night as well as to remove and store when not in use. Other options may include a higher quality insulation and hinging the shutter in order to facilitate operation and storage.

Benefits of this system include its relatively low price, good insulative quality, heat rejection capability and applicability to retrofit situations.

Disadvantages include the problem of storage when the shutter is not in use and the inconvenience of operating it.

Unless great care is taken when building and operating the shutter, problems of durability and edge sealing may occur. If the edge seal allows warm, moist interior air to make contact with the cold glass against which the shutter is being pressed, condensation and freezing will take place, effectively securing the shutter to the glass for the remainder of the winter season-which may have been the answer in the first place!

And of course the shutter size limitation can cause problems.

c) Pocket Shutters: These shutters, designed into the wall framework of a new home, are again sheeted rigid foam insulation. They slide on a track to cover the window areas when insulation is required and are stored within the wall when not in use. This simplifies the operation of the system, solves the storage problem, improves the reliability and durability. They provide good insulative value and can reject heat.

Understandably, though, they are expensive and do not amend themselves to retrofitting. Size limits of about 4 x 5 feet are typical.

d) Homemade Quilted Curtains: These curtains consist of a synthetic insulation (eg. polyester fibrefill) insulation faced on both sides by a decorative fabric and

quilted to hold the insulation in place. A polyethylene vapour barrier can be included as well.

They are inexpensive, aesthetically pleasing (when tie-dyed, batiked, quilted), are simple to operate and can be retrofitted. By using side valence pieces on spring hinges, and by including a polyethylene sheet within the quilt, good edge seals and an air/vapour barrier can be created.

However, tests have shown that this system is a poor insulator. Doubtlessly the greatest shortcoming of quilted curtain is their bulkiness which imposes severe size limitations on their application.

e) Multi-glazing: Though not a moveable window insulation, multi-glazing can meet any of the design criteria. This system consists of multiple layers of high transmittance glazing enclosing dead air spaces. They are protected between more rigid glazing material (such as glass, acrylic).

This system can provide a reasonable degree of insulation, avoids the difficulty of edge seals, is reliable, durable, and reasonably inexpensive if labour costs are not included. It may be difficult to retrofit but can handle large areas if a good job is done.

The complications are that it is difficult to do a good job installing the glazing film. The film must be stretched

taut so as to avoid wrinkles or other inconsistencies which would affect visual clarity. As well, the choice of glazing films is a complex issue,as shall be seen in later discussions of test results.

And lastly, the system has no inherent heat rejection capability. A curtain would have to be added to meet this need.

As can be seen, the owner-builder is hard-pressed to fabricate a window insulating system that satisfactorily meets the established design criteria. Commercial options, while relieving some of the inconvenience associated with fabrication and installation of the device,generally reflect the problems identified above with the various systems.

One further problem with commercial options is the general lack of availability. Most are fabricated in the United States and this creates inconvenience and often time delays for the Canadian homeowner. Of course, as the systems become more well-known and distributed, problems such as border crossings, long-distance communication and delays in delivery will be overcome.

Commercial options can be divided into generic categories as follows: exterior and interior shutters, quilted curtains, reflective curtains, combinations of quilted and reflective curtains, systems that are located within a double-glazed window, and infrared reflective coatings.

a) Exterior Shutters: These shutters can be further divided into two categories: rigid board insulation and rolladen types. The former resembles owner-built exterior shutters, incorporating rigid foam insulation (typically Thermax, an isocyanurate) into a wooden panel on hinges or tracks. They provide good insulation, can reject heat and are amendable to retrofitting.

Facing the same problems as owner-built options, they are limited in size to smaller installations. As well, their operation in inclement weather is severely impaired. And of course they are quite expensive.

Examples: Thermafold Shutters by Shutters,Inc.
- designed for use on sliding glass doors

Baer Shutters from Zomeworks Corporation
-owner built system by Steve Baer

Rolladen shutters have seen widespread use in Europe. These exterior wooden-slatted shutters are designed to offer privacy, heat rejection and to safeguard against vandalism. Several North American companies have attempted to duplicate this system using aluminum, wood or vinyl slats filled with urethane or dead air. Unfortunately, these shutters are being promoted as an insulating device rather than for the purposes for which they were originally designed. They are inherently poor insulators and allow air to pass along the edges and between the slats, although some products are

provided with fairly tight edge tracks. They are also limited in available sizes and are very expensive.

They do reject heat effectively, are applicable to retrofit situations and are effective at keeping burglars out-which was their original purpose!

Examples:	Pease Rolling Shutter	Pease Co.
	Rolcan Shutters	Rolco Manufacturing Ltd
	Serrande Shutter	Serrande of Italy
	Rolladen Shutter	American German Industries Inc.
	Therma-Roll Shutters	Therma-Roll Corp.

b) Interior Shutters: There are a large number of commercial options available in this category, and they vary both in their approach and expense. Insulation is achieved either by a sealed air space bonded by a reflective barrier, or by the use of foam insulation. An attractive wood facing is typically applied. The systems operate as bifold doors or on a sliding track.

These shutters are good insulators, provide good edge seals, are simple, aesthetic and reliable. Some can be retrofitted.

However, like exterior shutters, they are limited in size. They are also generally very expensive.

Examples:	InsulShutter	Insul Shutter Inc.
	Sunflake Shutter	Sunflake Window Company
	SunSaver	Homesworth Corporation
	ThermoShutter	Window Insulating Specialists Co.

ThermoShade manufactures a rolladen style of shutter which is a poor insulator and quite expensive.

Sun Mover, an insulating louver system, claims a high R-value and simplicity in operation.However, it is very expensive, has poor edge seals and interferes with viewing.

c) Quilted Curtains: Similiar to the owner-builder approach, these commercial curtains combine a synthetic batt insulation such as Hollofill, Dacron II, Polarguard or Thinsulate with an interior vapour barrier and exterior decorative fabrics. Edge seals (when used) are achieved using wooden side valence pieces on spring hinges.

They are relatively inexpensive and designed for retrofit situations. As well, they are aesthetically pleasing and, when edge seals are used, control perimeter air exchange effectively.

However, their insulative capability is relatively poor, as is their heat rejection. The spring-hinged edge seal system is inconvenient when used on a number of windows. Size limitations are imposed because of the bulk of the curtain (for example, Window Warmer sets an 8 x 8 foot size limit.

Examples:	Window Blanket	Window Blanket Company
	Window Warmer	Creative Energy Products

d) Reflective Curtains: These curtains consist of up to four aluminized fabric layers with air spaces between.

The aluminum performs as a vapour barrier and the interior-facing layer is mildly decorative.

This type of curtain is a good insulator (although manufacturers' claims of R9-R12 are questionable) and the material is impermeable to moisture movement. It is reliable, durable, amendable to retrofit situations, simple to operate.

The major drawback to the system is the lack of edge seals. Although the companies emphasize the need for edge seals, it has not been until recently that a system has been offered. It is generally left to the ingenuity of the owner to devise an adequate system. Further, the spacing of the multi-layers in such systems as Curtain Wall and Star Shade is dubious.

Finally, the cost of this type of curtain is still quite high.

Examples:	Insulating Curtain Wall (ICW)	Thermal Technology Corp
	Star Shade Insulating Shade (IS)	Star Technology Insulating Shade Co. Inc. (now defunct)

e) Combination Quilted and Reflective Curtains: These commercial products are the most well-known and best-selling insulating curtains - and with good reason. The quilt is a five-layer sandwich composed of outside decorative fabric layers, inside 1/4 inch polyester batting layers and a

centre reflective vapour barrier. The layers are laminated by an ultrasonic bonding process which does not perforate the vapour barrier.

These curtains are a relatively good insulator and come equipped with a good side seal system. They can cover moderately large glazed areas (maximum width is 99 inches). Large window areas on the new generation of passive solar homes, however, would require a number of individual curtains which increases both the cost and operating time involved (as well as perimeter heat losses).

The curtain is reliable, durable, simple to operate, aesthetic and easily retrofitted.

However, since the aluminized fabric is hidden within the five-layer sandwich, the curtain is unable to reject heat as well as desired. The light-coloured outer material does reflect some unwanted insolation but an aluminized exterior would be more effective. As well, the curtain is somewhat expensive. Note also the claimed R-value discrepancies amongst essentially identical products.

Examples: Window Quilt — Appropriate Technology Corporation

- edge seal system includes a cord sewn into the edge of the material. This cording runs inside a tubular track along the vertical edges of the curtain.
- typical cost is $9-$10.00 per sq. ft.
- good instruction and installation guide as well as a variety of information packages.
- claimed R-value of 5.2 with double glazed windows.

Thermal Shade

- edge seal system is composed of magnetic tape attached both to the curtain fabric and the window casings.
- curtain operates as roman shade.
- typical cost is $6.00 per sq. ft. (October 1981 price)
- claimed R-value of 4.1 with double-glazed windows

Warm Windows — Energy Alternative Systems, Inc.

- curtain operated as roman shade with magnetic tape edge seals.
- available in kit form for owner fabrication and installation
- cost similiar to Thermal Shade
- claimed R-value of 7.69 with single-glazed windows

f) Within Window Panes: One option currently being explored is that of interposing the insulating device between the panes of double-glazing. Two differing viewpoints on this topic exist.

Some writers, such as W. Langdon, accept that problems associated with interior insulating systems-interference with plants, people, furniture, disturbing an existing decorative window treatment-and with exterior ones-degradation caused by severe climate-can be avoided by placing the m.w.i. system within the glazing.

He does, however, note several problems associated with this approach. He writes, "The moisture condensation problem, a frequent occurrence in the space between

glazings, is aggravated by operating mechanisms for window insulation. Cords, pulleys, and other devices used should have close tolerances and proper seals to prevent the entry of moisture. Operating mechanisms that are moisture proof are difficult to construct with simple tools."

He further notes that a means must be found to completely remove the device during the daytime to allow the maximum amount of solar insulation. Even the limited amount of hardware associated with a reflective shade occupies a certain amount of space - however, it is possible to locate the device in an insulated pocket above the window.

There are some noteworthy benefits to placing the insulating device within the glazing layers, beyond those mentioned earlier. The problem of condensation on the interior pane of glass can be substantially alleviated as the temperature of this surface will be considerably raised.

"These higher glass surface temperatures," said M.H. Hodge at the 4th National Passive Solar Conference in 1979, "elevate mean radiant temperature, permitting reduced air temperature for a given comfort level." Lower air temperatures create lower delta T's between interior and ambient temperatures and hence reduce the heat loss.

A Canadian Company, Passive Solar Products out of Saskatoon, Saskatchewn, is manufacturing a reflective four-

layer curtain with magnetic edge seals. This curtain, Heat Trap, is located between the layers of glass, housed in lintel space, and operated automatically. Designed to respond to the large glazed area typical of passive solar homes, the curtain will insulate areas seven feet high and up to 20 feet in length with one motor.

The edge seal system appears to be quite effective at reducing convective flow within the panes of glass. The R-value of the system is quite high - the company claims an R-value of 12. However, tests at the University of Saskatchewan indicate R-7 for the four-layer system and R-4.5 for two layers.

Some drawbacks to this curtain assembly should be noted though. First, it is manufactured in discrete modules (58 x 85 inches), which limits the types of window openings it can accommodate. Custom fabricating is offered though.

Further, a substantial space must be allocated between window panes to accommodate the curtain and edge seal system - around 4 or 5 inches. This makes retrofitting an expensive and time-consuming task.

The cost of this curtain is somewhat prohibitive - $27 per sq. ft. for the drive module and over $21 per sq. ft. for the auxiliary ones. Of course, this cost includes window unit.

And lastly, the curtain must be operated automatically; there is no manual option.

Another commercially available system is Beadwall from Zomeworks, New Mexico. In this system, a vacuum pump blows expanded polystyrene beads into the space between the panes of glass (typically 2 1/2 inches) when insulation is needed. When thermal insulation is desired, the beads are evacuated.

This system is a good insulator - an R-value of 8.5 is claimed. By locating the system between the panes, the problems of edge seals and moisture permeability are avoided. One blower motor can handle the demands of a large glazed area although the area must be sub-divided into smaller modules. Beadwall is also an effective heat rejection system.

However, the system is very expensive and difficult to retrofit. Problems with the polystyrene beads acquiring a static charge and adhering to the panes of glass are also common. Bead 'powdering' due to sunlight degradation can also be a problem.

g) Infrared Reflective Coatings: The merits and liabilities of this system are difficult to discuss since, despite many years of research, the product is not yet commercially available. Many companies, though, such as the Southwall Corporation (manufacturer of Heat Mirror) and 3M (manufacturer of 3M High Transmission Film) are involved in researching the possibility of manufacturing this unique film.

The film would transmit short wavelength solar radiation while reflecting longer wavelength heat rays. That is, the solar spectrum (from .3 microns to just over one micron) is to be transmitted through the film while infra red radiation (3 microns to 80) is reflected back into the room.

The film is to be adhered either to existing panes or, ideally, located between the panes of glass. When a single layer is interposed between lites, a theoretical R-value of 4.5 is achieved. Again, the edge seal and vapour barrier problems would be avoided.

The major liability of the system, of course, is that it is not available. Until then, other criteria such as expense and ability to transmit solar gain cannot be judged. One problem which it will not be able to deal with is that of heat rejection.

In summary, through this examination of the various options on the market now, it is clear that a superior window insulation system has not yet emerged. Existing systems have developed techniques to alleviate some, but not all problems.

Shutters are generally expensive, inconvenient to operate and store and unable to respond to the needs of large glazed areas. Quilted curtain are bulky and do not insualte well. Quilted/reflective curtains have achieved good edge sealing systems but continue to exhibit some

problems. Because of the batt insulation which adds little to the insulative capability but much to the bulk of the curtain, this curtain is unable to insulate large glazed areas in a small number of modules. Also, the cost is still somewhat high.

Multi-layered reflective curtains avoid this problem of excess bulk by allowing the air spaces adjacent to low-emittence material to do the job of insulating. When the curtain is rolled up, these air spaces collapse and the curtain is quite compact and therefore able to insulate large areas. However, the commercial options do exhibit some flaws. They are expensive, have typically inadequate edge seals (with the exception of the Heat Trap) and strive to achieve unnecessarily high R-values. As indicated earlier,the relative merits of achieving a high R-value diminish rapidly beyond a certain level.

However, each of these commercial systems helps to define the characteristics of a superior moveable window insulation system. A highly-reflective, low-emittence interior double-layer curtain with good edge seals should be developed to meet all of the established criteria at a reasonable price.

2. RESEARCH AND DEVELOPMENT

ACQUISITION OF ALUMINIZED FABRIC

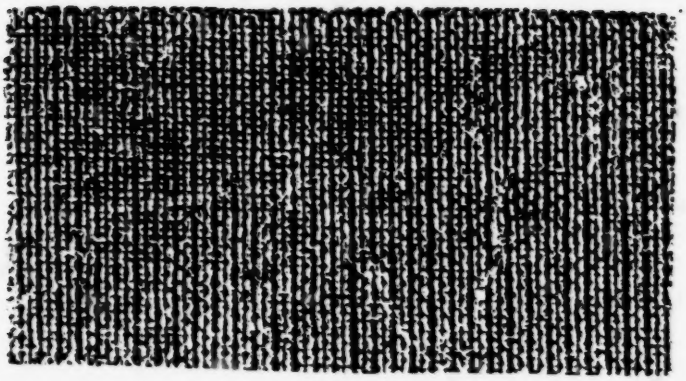
Having identified the weakest links in the development of a superior insulating curtain, we spent much of the September-December period assessing a variety of aluminized fabrics currently available, as well as re-examining materials on hand.The first aluminized material with which we fabricated curtains is a product called Foylon (Duracote Corporation).

Foylon 7018 (see attached sample, Figure 8a) is a material that has been attracting the attention of an increasing number of greenhouse, as well as residential, owners. It consists of .0003-inch aluminum bonded to a synthetic scrim backing. It is relatively inexpensive and our testing indicated that it achieved a reasonable R-value. (see Table 1)

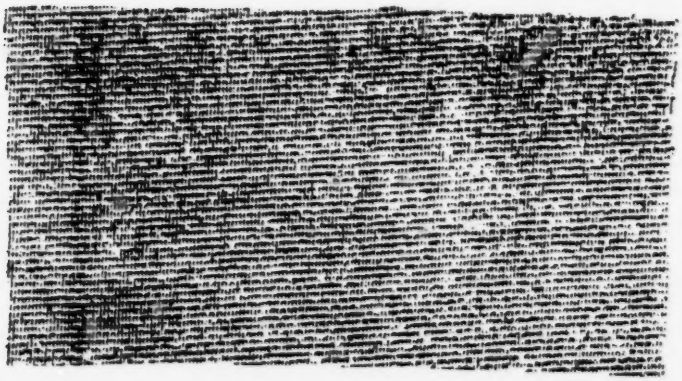
Unfortunately, it is not, in our experience, very durable. With a minimal amount of usage, the aluminum tends to delaminate from the scrim backing. As well, the exposed edges of the scrim frays easily. Since an insulating curtain requiring daily usage would have to be durable, we moved on to another fabric.

FIG. 8

FABRIC SAMPLES



A - FOYLON 7018



B - TRICOT

C - ARN

A more durable, though more expensive product than Foylon is an aluminized mood fabric (see Figure 8b). It consists of aluminum foil bonded to a synthetic tricot backing. Curtains made of Tricot and installed in winter/spring of 1981 have undergone daily operation in a number of homes and appear to be performing very well. Preliminary thermal testing indicated Tricot performed equal to or better than most aluminized fabrics. (see Figure 10)

The only problem incurred in using this material has been a major one. Given the knit (and therefore stretch) characteristic of the fabric, it is extremely difficult - and almost impossible- to sew the curtain straight and square. Because of this, the curtain does not track true when being raised or lowered. This in turn makes the possibility of a good edge seal extremely difficult, which is crucial to the insulative capability of the curtain.

Other commercial products available were avoided for a variety of reasons. For example, aluminized vinyl cannot be sewn into a curtain by the homeowner, precluding the possibility of providing the curtain in knit form. Further, thermal testing indicated that aluminized vinyl does not perform as well as other aluminized materials. This shall be elaborated upon shortly.

Another option, which is gaining popularity in large

drapery outlets such as Simpson's, Eaton's, etc., is an aluminized drapery liner. Such liners are typically fabrics coated with vacuum-deposited aluminum. Beyond the obvious lack of edge seals for this system, the thermal performance of this material proved unaccepable in later testing.

Given the lack of existing commercial fabrics which would meet our needs, we chose to find a company which would custom laminate a thin aluminum film to a stable weave fabric. After three months of fruitless telephone calls and letters it became apparent that this was not possible without a very long lead time and an unrealistic capital outlay.

We turned our attention to a product which is currently being used in some insulating curtain products - a aluminized rip-stop nylon (ARN-see attached sample Figure 8c). Preliminary testing in November indicated a slightly lower R-value than that of the Tricot but this shortcoming was felt to be acceptable in comparison to the obvious merits of the ARN; that is, availability, relative low cost, durability of rip-stop nylon, evenness of weave and ensuing stability, uniformity in manufacture, reliability of manufacturer.

In mid-November, we placed an order for this fabric. Despite a quoted delivery time of four to six weeks, it was not until March, 6, 1982 that the fabric arrived. Several

curtains were then immediately fabricated and feedback gathered. As well, this allowed us to finally intensively assess the thermal performance of our curtain system with this fabric.

TESTING:

Although procedures appropriate for testing window insulating systems have been outlined (ASTM C236-66), few facilities exist in Canada which can meet these needs. Further, there are major discrepancies between manufacturers' claims of R-values and those recorded by testing laboratories, between those recorded by private labs (such as Rodale Design Center) and manufacturers' results, and even between claimed R-values of similiar but competing products. Examples of these discrepancies were noted earlier in the discussion of commercial quilted/reflective products.

Given the number and variety of testing situations and fabric samples which we wanted to test, it was not feasible to engage or rent existing facilities at, for example, the University of Saskatchewan or NRC in Ottawa. We therefore decided to establish testing facilities at our workplace near Carstairs. The facilities and tests were established and conducted as outlined in the following.

We used a standard residential vertical (stand-up) freezer. The door was removed and replaced with a

continuous two-inch slab of extruded polystyrene (Styrofoam). It was sealed in an air-tight fmanner to the freezer opening. A small (8 inch x 8 inch) double-glazed window was inserted in a rabbetted "window" hole. The glass lites were separated with half-inch SM strips and the unit was siliconed together. Just prior to sealing, a HiCal heat flux meter was secured to the interior of the glass away from the freezer. It was adhered to the center of the window with a common electronic heat sink cement. A small "muffin" type computer fan was located within the freezer to simulate a winter wind condition.Temperature transducers were centrally located about three inches from the window on each side. Delta T's were typically in the range of 65 Fahrenheit degrees. Readings were taken of the double glazing itself and in conjunction with a number of standards. The standards used were a range of thicknesses - 1/2 inch to 1 1/2 inches in quarter inch increments - from a Styrofoam sheet. Then a large number of fabric samples (and composites) were tested. Sufficient equilibration time was allowed for each test. The results obtained were highly reproducible and linear.Their accuracy is not, however, absolute.

Preliminary testing took place in October 1981 and attempts were made to reinforce or upgrade the validity of the test method. We contacted several engineers at a number

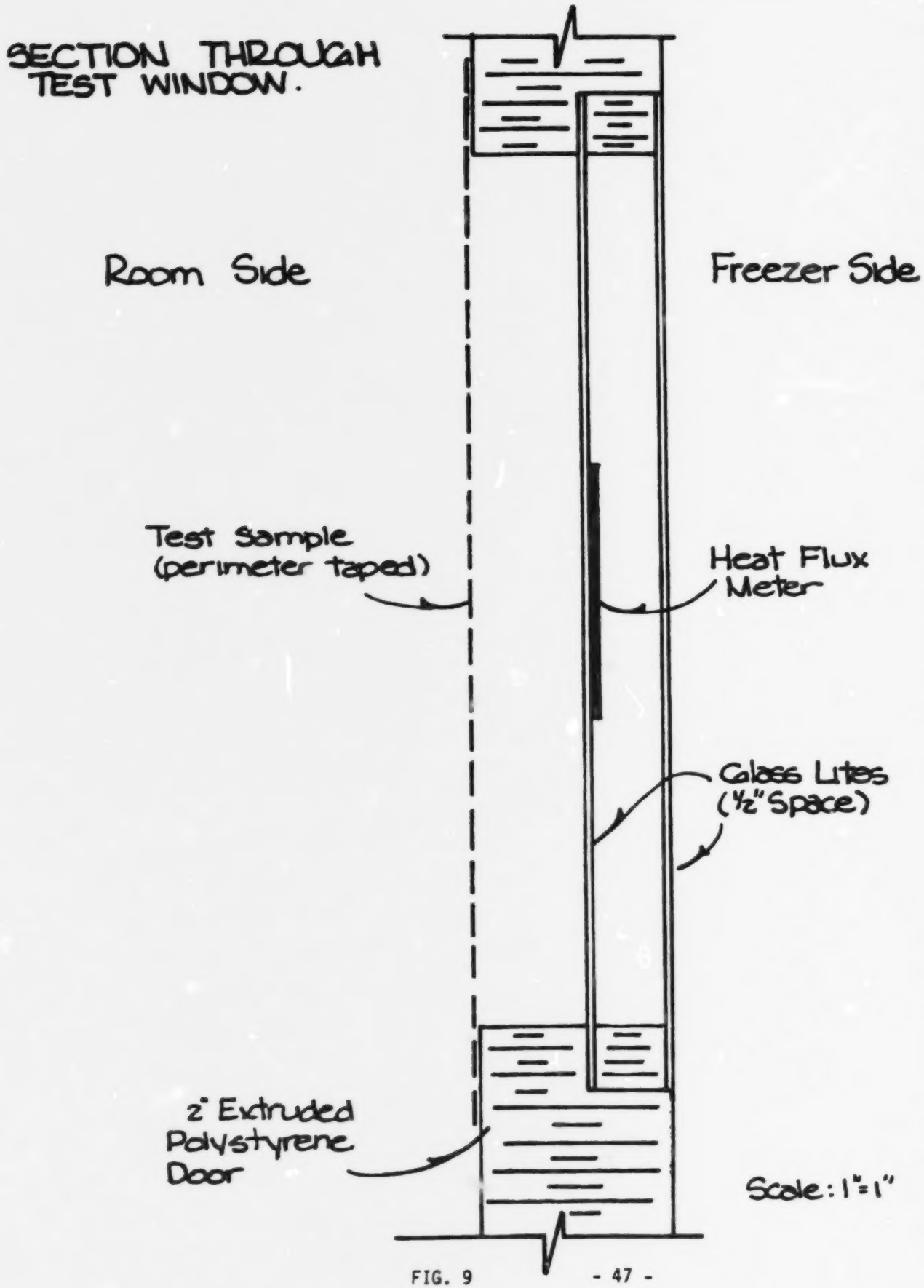

SECTION THROUGH
TEST WINDOW.
Room Side
Freezer Side
Test Sample
(perimeter taped)
Heat Flux
Meter
Glass Lites
(½" Space)
2" Extruded
Polystyrene
Door
Scale: 1"=1"

FIG. 9

of research centres to receive critiques of our testing procedure. Contact included Bernie Luft, Alberta Research Council; C.O. Handegord, National Research Council, Ottawa; C. Hedlin, NRC, Saskatoon; Harold Orr, NRC, Saskatoon; Rob Dumont, NRC, Saskatoon; Bob Besant, Department Head of Mechanical Engineering at the University of Saskatchewan.

From these sources, a range of responses was elicited. Since Alberta Research Council does not have the facilities to conduct the tests which we required nor the history of interest in this field as NRC in Saskatchewan, most of the critiques come from the latter.

Dr. Handegord expressed enthusiasm towards the testing method noting that "the results you have obtained are surprisingly good. (We suggest) that your set up might be a reasonable arrangement for a first evaluation."

To improve the testing procedure, we had suggested three refinements:

1) simulating a "black body" within the freezer to provide more accurate representation of emissivity
2) conducting tests on a horizontal plane to mitigate convective influence
3) varying the delta T's

Responding to these suggestions, Dr. Handegord and a colleague, Dick Solvason, (Head of Thermal Properties Section of NRC in Ottawa) replied:

1) "the freezer probably has a high emissivity for long wave radiation"

2) "as a practical test, it is probably better to maintain a vertical orientation"

Dr. Hedlin, head of NRC's Regional Station in Saskatoon, agreed that the test results were notably consistent and that the testing arrangement and procedure appeared reliable. He did note that the placement of the heat flux meter within the experimental arrangement added an unknown variable but added "that is typical of the scientific dilemna - the experimenter always creates interference within the experiment." To balance the effect, he suggested that we connect thermocouples in series on opposing sides of the material being tested to create a continuous heat flow meter.

The most severe criticism of the testing method came from Harold Orr. He maintained that several flaws in the procedure cast severe doubt on the credibility of the results.

Firstly, he noted a double-glazed window does not provide a stable resistance to heat flow of U=.56. Because

of the temperature differential and the 1/2 inch air space, a convective flow will be established within the double paned unit. This will create a range of delta T's and a subsequent range of R-values. Thus, he argued, the placement of the heat flow meter will be a determining factor in the resultant R-values registered - placing the meter in the middle of the glazed area will not provide a suitable average result.

Further, he indicated that the heat flow meter itself creates a distortion of the results. Because it represents additional mass, and conducting surface within the experiment, it will encourage heat flow where it is situated and therefore produce artificially low R-values. Despite the meter's small size (2 inches by 3/4 inches by 1/8 inch thick), Mr. Orr believed it would create significant distortions in the results.

And lastly, he drew attention to the potential influence of the freezer cycling. With an unstable cold side to the experiment, the results would not be reliable. He did not believe that the mass (buckets of water) placed within the freezer would provide an adequate thermal tempering of the interior.

In contrast to the doubts raised by Mr. Orr, the comments by Rob Dumont corroborated those of Drs.Handegord

and Hedlin. Dr. Dumont suggested that although the criticisms made by Mr. Orr were valid and that the suggestions which he made would improve the credibility of the results, the improvements would be marginal. Given a much larger budget and access to facilities, he said, a more accurate test can be conducted. However, he added, an accuracy of "about twenty per cent" could be attributed to the method which we use. Because the results from the preliminary tests were reproducible and linear, he believed that our approach gave adequate, reliable data for comparison.

These comments substantiate those made by Robert Flower, Engineering Consultant to the Rodale Press Design Center in Pennsylvania. In tests using a somewhat similiar approach to ours, he claimed an "absolute accuracy of ... approximately $\pm$ 15 per cent."

Bob Besant restricted his comments to the insulative capability of the curtain system. The University of Saskatchewan has developed a climate control lab which can be used to test the insulating properties of materials. Mr. Besant's experience with these facilities and results of his testing led him to offer the following comments:

a) An effective edge seal system is crucial to the thermal performance of the curtain. R-values can be dramatically reduced without proper edge seals.

b) The insulative capability of the curtain would probably be increased if both layers of fabric were sealed separately; that is, if both layers acted independent of each other.

c) Given his experience in the lab, Dr. Besant suggested that a reasonable R-value to expect from our curtain system would be around 3.

Modifying our testing methods with suggestions from the above sources, we began a second round of testing in March 1982. The refinements on our original testing procedure were as follows:

1) Single glazing to reduce convective influence within the window system.

2) An additional fan - directed across the warm side of the system - to equalize convective influences on the materials tested.

3) An expansion of the tested materials to include a brief sally into the world of multi-glazing. Included in the tests were sample of polyethylene, acrylic, polyester, polyvinyl fluoride (Tedlar) fluorinated ethylenepropylene (Teflon), plate glass and glass-reinforced polyester. The theory upon which this apparent digression was based centre upon the varying abilities of the above listed materials to transmit long-wave infra red radiation.

A selective list of materials tested follows. Note that the R-values recorded have significance only for relative comparison. Values from one test regime should be compared only within that test regime. Each test incorporates a different range of variables eg., delta T's, glazing materials, test sample size.

Further, all results presented were recorded without the use of the exterior fan (although a fan on the cold side of the freezer was used). This will add a degree of practicality to the discussions, since winter wind conditions are realized only on the exterior side of a typical glazed area.

Also, many tests were performed with up to six temperature sensors at various locations. This provided us with an accurate measurement of the temperature gradient across the experimental set-up.

TABLE I

TEST #	MATERIAL AND PARTICULARS	R-VALU
1	Double glass	1.6
2	Aluminum foil (Reynolds Wrap)-bright side to freezer	4.0
3	Aluminum foil - dull to freezer	3.8
4	Al foil with tan acetate hung loosely in front	4.1
5	Tricot - Al. to freezer	3.4
6	Tricot - Al. to room	2.8
7	Double laminate Tricot bonded with white glue (Al face both ways)	3.4
8	Al foil bonded to one side of white nylon (Al exposed)	3.6
9	Al foil bonded to both sides of white nylon	3.9
10	Aluminized polyester ('space blanket')	3.4
11	Heavy dark blue taffeta (Al to freezer)	3.1
12	Black aluminized vinyl (Stauffer Chemicals)	2.9
13	White aluminized vinyl (Custom Coating)	3.2
14	Verosol (312-7025) - deposition directly onto fabric	2.6
15	Window Quilt - 5 x 6 inch sample	3.6
16	Polyester fibrefill-two inches, faced with fabric	3.6
17	White paper	2.2
18	Bubble PaK	2.3
19	FRP - .040 inches Glasteel with Tedlar coating	2.5
20	1/8 inch styrene	2.6
21	2 mil polyethylene	2.2
22	One inch SM	6.4
23	Duracote Foylon 7018 - Al side to freezer	3.0

NOTE: Testing utilized an 8 x 8 inch window in a two inch SM freezer door . Double glazing (with glass) was used.

TABLE 2

TEST #	MATERIAL AND PARTICULARS	R-VALUE
24	Astrolon 8 - white aluminized vinyl with Al to freezer	2.3
25	Astrolon 8 - white aluminized vinyl with white to freezer	2.3
26	Astrolon 1 - green aluminized polyethylene with scrim - Al to freezer	2.7
27	Astrolon 1 - green aluminized polyethylene with scrim - green to freezer	2.6
28	Solar Shade - white al'd vinyl - Al to freezer	2.6
29	Solar Shade - white al'd vinyl - white to freezer	2.5
30	Aluminized polyester (thin aluminized deposition)	2.9
31	Tricot - Al to freezer	2.7
32	- fabric to freezer	2.6
33	ARN - gold to freezer	2.5
34	ARN - nylon to freezer	2.5
35	Two layers of ARN - layers separated and sealed with gold to freezer	3.9
36	- curtain simulation with spacer tube (loop)	3.4
37	- loop but no spacer	2.8

NOTE: Testing utilized a 12 x 12 inch window in 3 - inch SM door. Glazing was one layer of a acrylic.

TABLE 3

TEST #	MATERIAL AND PARTICULARS	R-VALU
38	Polyethylene (cold side) - polyethylene	1.8
39	" - teflon	1.9
40	" - polyester	2.2
41	" - glass	2.6
42	" - acrylic	2.6
43	Glass + glass - one inch gap	1.9
44	Glass + glass - 3 1/4 inch gap	1.9
45	Glass - polyethylene - polyethylene - glass	2.8
46	Glass - teflon - teflon - glass	2.9
47	Glass - polyester - polyester - glass	3.9

TABLE 4

48	Aluminum foil with shiny side to freezer	1.9
49	Aluminum foil with black side to freezer	1.9

NOTE: The testing material consisted of two layers of aluminum foil laminated together with thermal cement. A temperature sensor was placed within the lamination before bonding. One side was then painted with a flat black paint. Temperatures recorded within the lam in test 48 were 51 degrees F and in test 49 were 36 degrees F.
Glazing was one layer of glass.

TABLE 5: IN SITU TESTING (ARN MATERIAL)

TEST #	CURTAIN PARTICULARS	R-VALUE
50	Double glazing	1.9
51	Curtain with no side seals (heat flow meter in middle of window)	3.1
52	Curtain with no side seals (heat flow meter adjacent to edges)	3.1
53	Curtain with corded edge in edge track (HFM at top of window)	2.0
54	Curtain with corded edge in edge track (HFM in middle of window)	4.4
55	Curtain with corded edge in edge track (HFM at bottom)	6.0
56	Curtain with taped edges (HFM in middle)	4.4

TABLE 6: IN SITU TESTING (with Tricot Material)

57	Curtain with top seal	4.4
58	Curtain without top seal	4.2

TABLE 7: Reflectivity Comparisons

A - Tricot - aluminum exposed
B - ARN - aluminim exposed
C - ARn - white nylon exposed

A	B	C
108 F	116 F	
144	155	
140	148	
132	141	
103	103	105 F
106	106	115
134		140

NOTE: Fabric samples were tested in two identical double-glazed test cells, each two feet square, with R12 back insulation and R6 edge insulation. Temperature transducers, shielded from direct radiation, were used to record stagnation temperatures under a wide range of insolation regimes.

CONCLUSIONS FROM TEST RESULTS:

Before delving into the vast and complicated realm of infra red control using low emittance surfaces, it would be useful to note other interesting results.

First, the application of two inches of polyester fibrefill, a synthetic batt bulk, it performed only marginally better than aluminized polyester (Tests 16 vs.10, 3.6 vs 3.4). This should certainly knell the death toll for fibrefill insulation as an insulating curtain material, given its already-mentioned handicaps of bulk and difficulty of edge seals.

Examining some commercial products, it is worthwhile that here too the batt insulation does not significantly increase the R-value. This insulation is used in both Window Quilt and Warm Window, in conjunction with an interior layer of aluminized polyester. However, a single layer of aluminized polyester performs nearly as well (Tests 15 vs. 10), indicating that it is providing the major insulating value to this curtain.

Let us further note that neither the colour (white, tan, dark brown) or the composition (polyester, acetate, nylon, cotton) of the fabrics altered their thermal performance. The samples rated the same (around R2.2) as 2 mil polyethylene or white paper indicating that the only

contribution came from the additional air space created by the fabric.

More interesting conclusions can be drawn from assessing the results of the aluminized fabric tests.

Some of the most common insulating materials in the market such as Verosol, Met-L-Chine and common drapery liners are manufactured by the direct vapour deposition of aluminum onto the substrate fabric. The thermal performance of these products was significantly poorer than that of products such as Tricot and ARN. (see tests 5 vs. 14, for example). These aluminized fabrics are composed of vacuum-deposited aluminum which is sandwiched between two layers of polyester film before being laminated to a fabric backing.

Second, the insulating value of the fabric generally is similiar or slightly better when the aluminum side faces the cold exterior (see tests 2 vs. 3, 5 vs. 6, 24 vs. 25, 26 vs. 27, 31 vs. 32, 33 vs. 34).Especially in tests 48 and 49, it was noted that the R-value did not change when the side facing the freezer did. This occurred despite noticeable differences in the temperature of the foil. How can this be?

An explanation can be offered when the reflective and emittance properties of the aluminum foil are scrutinized. In test 48, with the black side facing the room, the

temperature of the foil was quite high (51 degrees F). This is because the black is such a poor emitter, the naked side facing the freezer was unable to re-radiate this heat. When the foil was reversed, the temperature of the foil was quite low (36 degrees F). This is because the aluminum reflected most of the radiant heat incident on it from the warm room. The black side facing the freezer freely emitted what little heat was accumulated. It appears, at these temperatures, the emittance properties are of similar importance to the reflective properties for the conservation of radiant heat.

In order to capitalize on these properties, would it not be more effective to have both sides of the fabric faced with aluminum? As tests 5 vs. 7 indicate, when Tricot was used as the double laminate, this was not the case. However, this supposition did hold true when a nylon/naked aluminum laminate was tried (as in tests 8 vs. 9). We can suppose that the fabric backing doesn't further degrade the properties of the aluminized polyester. Rather the polyester film which protects the aluminum is responsible. A more detailed examination follows.

Finally, a single layer of naked foil dramatically outperforms all other materials tested. And though it is not as effective when bonded to a fabric (4.0 to 3.6, tests 2 vs. 8), it is relatively unaffected by having a decorative

material hung loosely in front of it (tests 2 vs. 4). In fact, a very slight improvement in performance was noted.

Ideally then, one would prefer to use naked aluminum foil as the insulating fabric. However, aluminum foil is not durable enough to withstand the rigours of daily operation, edge seal strain, and all the hazards that accompany the use of an interior shade. In consultation with the foil specialist for Alcan of Canada, Ltd., we were told that it was essentially impossible to expect a lamination of foil sheet to provide the kind of reliability which we require. To obtain the durability and flexibility essential to an insulating curtain fabric, the aluminum must instead be vacuum deposited onto a substrate. This substrate typically involves a very thin plastic film on either side of the aluminum deposition. This sandwich is then laminated to a strong backing material such as nylon or vinyl.

Some manufacturers such as Duracote, claim that no such film is applied to their product. Therefore we would expect that their Foylon would perform somewhat better than a product protected with plastic surface coatings. In fact, our tests have not shown this to be the case (tests 5 vs. 23, 10 vs. 23). Why is this?

We have observed that Foylon has a very rough surface

finish, encouraging the oxidation of the exposed aluminum. In fact, one of the drawbacks to using this product is this oxide coating which rubs off easily with contact. We originally concluded that this oxide coating inhibits the emittance/reflective properties of the aluminum foil. Household aluminum foil, such as that which we tested, does not exhibit this oxide problem. To resolve this apparent anomaly, we questioned technical staff at Alcan. They assured us that their aluminum foil, as all untreated aluminum products, does indeed oxidize.

Therefore, we speculate that the Foylon is a unique foil product and as its dull colour visually suggests, does not exhibit the reflective/emittance properties. What should this substrate be?

If the substrate selected is a high IR absorber, it will negate the high reflective value of the aluminum. In a discussion with Fuller Moore at the 1980 Passive Solar Conference, he argued convincingly that polyethylene should be the laminating material. This suggestion was based on the belief that polyethylene is far more transparent in the relevant spectral region. This would not negatively impact the ref./emit. properties of aluminum foil.

For these reasons, we conducted a series of tests on various glazing products to compare their IR performance.

There are a range of products, each with its own unique spectral characteristics. Figure 10 indicates some of the better understood spectral information on some of the most common materials.

There are some obvious limitations to a chart such as this. To say that a material has a 20 per cent transmission of the longwave radiation beyond 2.5 microns is of little value to us since it does not pinpoint the region of interest to us, that is the 5 to 10 micron range. We would be far more interested in a transmission curve over a large spectral range such as that given for Teflon in Figure 11.

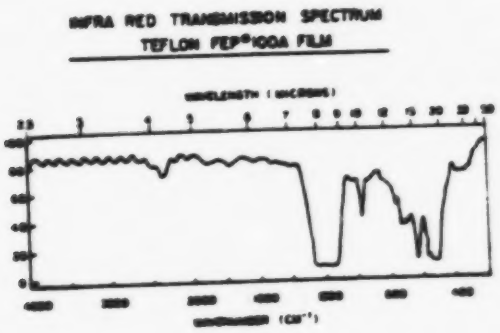
Even a representation as accurate as this graph can be somewhat misleading. It suggests that the material has been studied in discrete bands i.e., 5 microns and then 6 microns, and the line between these two bands was then extrapolated. However, the transmission ability of most materials can vary significantly over a very short range - this variance would be unnoticed in graphs such as this.

Returning to our test analysis, we note the following: From Table 3, tests 38 to 41, the results indicate that polyethylene has a slightly lower R-value than Teflon which is notably less than that of polyester. Glass, along with acrylic, has the higher R-value. We are led to believe that the far infrared transmission characteristics follow a

FIGURE 10

GLAZING MATERIAL	Longwage Transmission(greater than 2.5 mic)	
	from Ref. 11	from Ref. 13
GLASS (1/8 inch)	.03	.02
POLYETHYLENE - 4 mil	.80	.81
FIBER GLASS - 25 mil	.12	.08
POLYESTER - 5 mil	.32	.18
POLYVINYLFLUORIDE - 3 mil	.43	.23
TEFLON - 1 mil		.26
ACRYLIC - 1/8 inch		.02
POLYCARBONATE	.06	.02

FIGURE 11



similar pattern. That is, polyethylene is a poorer insulator because it transmits high in the far IR range. Glass, being a low IR transmitter, performs noticeably better.

We then attempted to extrapolate these patterns to the aluminized materials on hand. For example, one material available was aluminized vinyl. This is becoming quite common in the laminating industry. Because of its acceptable characteristics of cost, durability and availability, we decided it worthwhile to test some of our samples. In tests 24 vs. 26, we noted that the aluminize polyethylene (Astrolon I) performed significantly better than aluminized vinyl (Astrolon VIII).This suggests that the vinyl is negatively affecting the ref./emit. properties of the aluminum to a greater extent than the polythylene - we again speculate this to be a result of low far - IR transmission property of the vinyl.

We then compared aluminized polyester to aluminized vinyl and found it performed significantly better (tests 30 vs. 24 and 28). This can be readily explained. We know that aluminized vinyl is actually an aluminized polyester further bonded to a vinyl backing. Thus there is additional IR absorption by the vinyl, lowering its insulative capability.

The comparison between aluminized polyethylene and aluminized polyester did not however produce the expected results. Since polyethylene is generally understood to transmit better than polyester in the far IR radiation range, we assumed that, when these materials are aluminized, that it would outperform aluminized polyester. Tests indicte otherwise (30 vs. 26). Why is this?

We noted that the aluminized surface of the polyethylene was much duller so we contacted the manufacturer of the aluminized polyethylene to inquire. We were told that this dullness is an inherent property of the reaction process of vapour depositing onto polyethylene. Perhaps the poor performance of aluminized polyethylene is a result of this dullness;analagously, as earlier noted, the performance of dull Foylon was surprisingly poor.

Also, our knowledge of the spectral transmission of polyester in the far IR region is somewhat vague. A literature survey seeking out spectral distribution curves of polyester was not particularly rewarding since again, the studies dealt only with very discreet wavelength bands. Polyester is generally assumed to have low transmission in the relevant range ie. 32 per cent from Figure 10.

Ideally, however, we would prefer that the protective coating on the aluminum would transmit a much higher

percentage of the far IR radiation. Unfortunately, our choices are somewhat limited to the manufacturers' products. Aluminized polyethylene is inappropriate for insulating curtain material since polyethylene degrades in the presence of ultraviolet radiation. Since the curtain is often used to reject unwanted solar gain this becomes a major drawback. Even behind glass, the material would be affected over time, thereby shortening the life span of the curtain.

Aluminized polyester is far more durable but absorbs much of the far IR radiation. Aluminized vinyl shares this shortcoming to an even greater extent.

There are a few other materials that should possibly be examined. We have, for example, received very small samples of an aluminized vinyl, it is probably an aluminized polyester further bonded to a backing material. Unfortunately, the sample swatches were too small to adequately test. Further, it has certain aesthetic disadvantages; for instance, it readily forms permanent unsightly wrinkles.

Another material which offers greater promise would be aluminize polypropylene. We have unfortunately been unable to discover a source for this material. We are presently locating polypropylene film to compare relative radiant insulative value with other films we have tested.

The basis for selecting polypropylene is its supposedly favourable far - IR transmission characteristics. This, after all, has been our primary assessment tool - and IR transmission properties of the substrate films. However, we must recall that the high thermal performance of aluminum foil depends not only upon high reflectivity, but also low emittance of far IR radiation. We have neglected the emittance aspect,perhaps understandably since so little data is available on this property.

As earlier reviewed, these properties are of similiar importance. Some anomalies in our test results might well be attributed to the overriding effects of the emissivity of the protective substrate films.

Of course a number of other variables are no doubt influencing the performance of the aluminized layer. These might include:

a) the thickness of the aluminum deposition
b) the varying reactions of aluminum vapour to the substrate film
c) different additives (for example, plasticizers, uv inhibitors, etc) in the manufacture of the plastic films.

These problems no doubt explain why our tests indicate a relatively low value for ARN when compared with a more typical aluminized polyester, (tests 33 vs. 31). An

attractive characteristic of the ARN was its aesthetically pleasing bronze colour. This has been bought at the cost of introducing a dye to the polyester film - which may negatively impact the thermal performance by absorbing far IR radiation.

PERFORMANCE ASSESSMENT OF ARN:

The ARN material performed reasonably well, with a single layer attaining an R-value of 2.5 in conjunction with acrylic. Two layers of the ARN with an accompanying air space gave an R-value of 3.9 again with acrylic.

The "in situ" testing corroborated the results of the test cell experiments. An R-value of 4.5 - 5.0 in combination with a large (8 x 7 foot) double-glazed unit was achieved.

The R-value varied dramatically, depending on the location of the heat flux meter. A possible conclusion from this finding is that convective currents are being established within the air spaces created by the curtain. At the bottom of the system, results as high as R6.0+ have been recorded. At the top of the window, though, the curtain appears to add little insulative value to the double glazing (tests 53-55).

The tests also showed our edge seal system to be very effective at reducing perimeter losses. Without side seals,

an R-value of around 3 was noted. With side seals in place, this value was raised to 4.5. When the edges of the curtain were taped to the window casing, creating near-perfect edge seals, the R-value increased only negligibly (0 - 0.2). See tests 51,54 and 56.

One accidental recording occured when the curtain was lowered to within 1/4 inch of, but not quite touching, the sill. The R-value dropped substantially in this situation, emphasizing the importance of an effective bottom seal.

The top seal proved moderately effective during the tests. When it was removed a consistent drop in the R-value of 0.2 was recorded.

One further mechanical function of the curtain was experimented with in the test cell. Typically, spaces between the two layers of curtain fabric are maintained with polyester spacer strips. When these were removed, the R-value of the curtain dropped to that of a single-layer,well-sealed curtain! (tests 35 vs 37 vs 33)

EDGE SEAL SYSTEM: Having determined that the aluminized rip-stop meets the major criteria for insulating curtains (that is, cost, adequate insulative capability, durability, stability) we began fabricating curtains using the edge seal system which developed during the early months of the program.

As previously noted, effective edge seals are crucial to the thermal performance of a curtain. Sealing the top and bottom edges of the curtain proved simple. A weight is needed in the curtain to pull it down. This weight ensures that the curtain bottom will rest continuously along the sill or floor when fully extended, reducing air leakage.

A top seal is provided by a loop of 2 mil polyethylene draped over the length of the curtain inside the top valence (see Figure 12).

Side seals represent more of a challenge. One system which proved satisfactory for small, accessible windows consists of wooden valence strips secured to the window easing with spring hinges. Foam weatherstripping is allowed along its length (see Figure 13). These valence

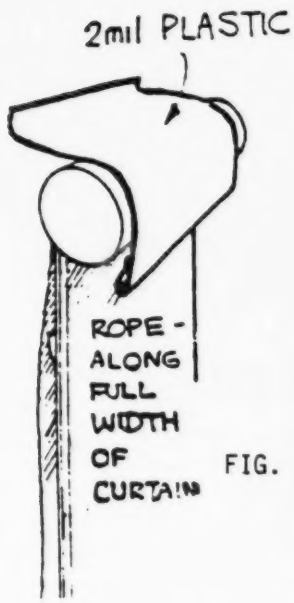


FIG. 12

FIG. 13

pieces tightly clamp the curtain edges when the curtain is rolled down at night and can be opened to allow the curtain to be rolled up when desired.

Although simple, inexpensive and effective on small windows, the spring hinge system is difficult to operate on large or hard-to-access windows. Further, in houses where several curtains are installed, the inconvenience of opening and closing a pair of valences for each curtain would be unacceptable to most homeowners.

A review of commercial options for edge seals made apparent the problems which other companies were encountering in reducing convective loss. Early curtain manufacturers such as Insulating Curtain Wall (ICW) and IS, suggested that the homeowner construct wooden U-shaped channels to mount on the side of the window casement. The curtain edges would travel in this channel, reducing some air exchange. A further refinement by IS involved the development of a pliable vinyl extrusion which was mounted within the U-shaped channel, providing a more airtight fit. Though somewhat ineffective,the idea is probably a sound one, especially for large curtains where perimeter losses have less overall effect, relatively, on the thermal performance of the curtain. A closer re-examination of this option will probably be undertaken in the upcoming months.

Many companies have provided only the fabric and (usually) the operating hardware for their product, without supplying an edge seal system. More recently, though, there has been an increased awareness of the importance of edge seals. ICW has more recently begun including an edge seal system in their curtain assembly.

Magnetic edge seals have attracted the attention of other companies. Some, such as Wind'n'Sun Shield by Boyle Industries require the homeowner to manually press the seal into position along the perimeter of the curtain. Others, such as Thermal Shade and Warm Window, have fashioned a roman shade quilted curtain that uses magnetic tape to seal the side and bottom edges. Unfortunately, in our experience,this seal has proven neither reliable nor effective.

One commercial product which provides an effective magnetic edge seal is Heat Trap, from Passive Solar Products. Both layers of this aluminized curtain are sealed with magnetic tape - the curtain appears to be laid on and peeled off of the magnetic tape very smoothly and reliably providing an effective edge seal.

An attractive, simple, inexpensive and effective method of sealing the curtain edges is to sew cording into the curtain edges and track the cord in a matching channel along

the window casing. This system, a developmental extension of the sailtracks used on sailboats, is one that we have found most promising and have directed much effort towards refining it. To simplify sewing by the homeowner, we have begun fabricating the piping (the cord sewn within the fabric flange), requiring that the homeowner simply sew the piping to the curtain edges.

Custom extruding the matching channel was undertaken in November. Dyes were designed to extrude a slotted tubular pvc track only a half inch in total width (see Figure 14). A tan colour was chosen in an attempt to complement exisitng window casing material.

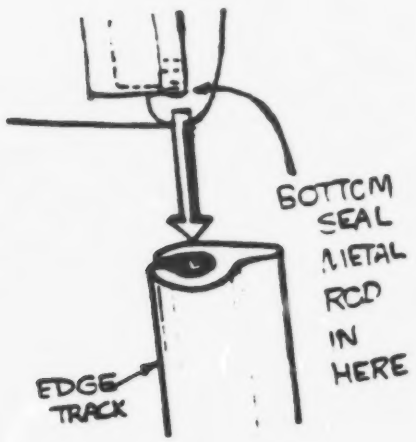


FIGURE 14

Tests were conducted "in situ" at an actual curtain installation site to determine the effectiveness of the side seals. As previously noted, (p.42) the use of this system had a profound effect on the R-value of the curtain. From these results, it can be seen that our edge seals are very effective.

Some problems have been incurred using this system. Because the piping is somewhat thicker that the curtain fabric, its diameter on the aluminum roller tube expands more quickly. It was for this very reason that we began manufacturing our own piping - the cord in commercial piping is significantly larger and aggravates this problem. Subsequent difficulties can be encountered when the piping is fed back into the edge track as the curtain is lowered. Even with the smaller piping, these difficulties may limit the application of this edge seal system to curtains of about ten feet high.

For this, and other reasons, we have not culminated our search for an effective edge seal system. Magnetic tape continues to attract our attention. So too does the simple jam seal. Perhaps for smaller window, the piping/edge track system is best. For larger window, however, it is worth considering a simpler, if somewhat less effective, edge seal, especially if operation is to be automatic.

SPACING OF CURTAIN LAYERS:

Another aspect of our curtain system which attracted attention was the development of an effective method of maintaining an air space between the layers of fabric. In order that the reflective/emittance properties of the aluminized fabric perform effectively, air spaces must theoretically be maintained adjacent to the aluminized surface. This was reinforced by our tests, as the R-value of a double-layered curtain dropped from 3.3 to 2.8 when the spacers were removed. (tests 37 vs. 35)

A simple method of maintaining an air space involved gluing a one inch polyethylene foam strip along the top of the curtain (on the inside of the outer curtain layer). Although this method was inexpensive and reliable, it created some problems. Despite the slight weight of the foam, it created an imbalance in the ascent and descent of the curtain, causing a "cam" effect. As well, the foam skewed the symmetry of the roller tube and subsequently caused problems in feeding the cording into the edge track.

In January, we contacted a heat-forming company in Calgary to enquire about forming polyester spacer strips which would separate the two curtain layers but conform to the shape of the aluminum roller tube (see figure 15) These strips have proven quite effective -and much simpler than gluing foam strips!

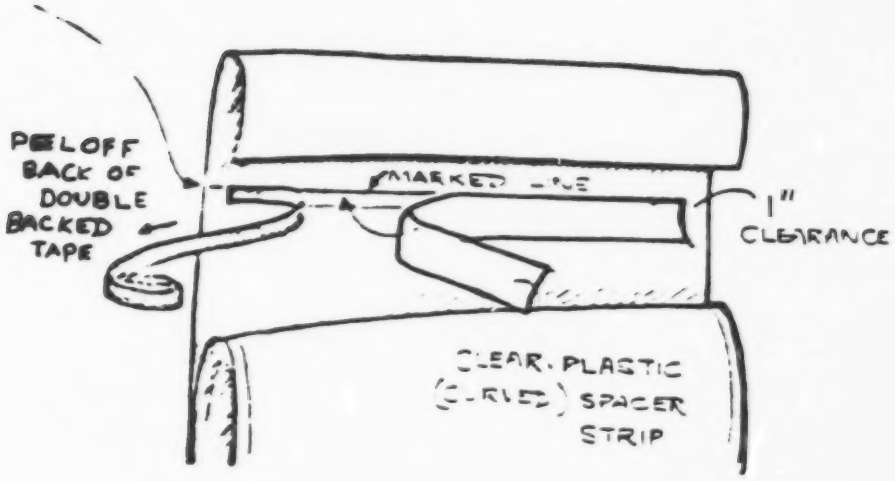


FIGURE 15

With the curtain layers held apart at the top, we turned our attention to the bottom. For many months we had been using a simple 1/2 inch cpvc tube to act both as weight and fabric separator. Because of the diameter of this spacer though, any window casing or similar protrusion along the path of the curtain's ascent had to be removed. With the success of the polyester spacer strips, we abandoned the tube and replaced it with a 1/4 inch steel rod. Above the rod, we secured another spacer strip. Again, the strip proved effective in creating the essential air space.

ANGLED GLAZING:

A noticeable gap in insulating curtain technology has been the lack of options for homeowners with angled glazing. Angled glazing not only accelerate heat loss but can be

plagued by overheating problems during the summer months. A reflective insulating curtain should be able to be designed to mitigate both of these problems.

During the January/February period, before the new fabric had arrived, a concerted effort was directed towards refining our system to be adaptable to angled glazing. A complex system of pulleys and elastics was developed which is very reliable, but quite difficult to install and has a questionable effect on the aesthetics. It does however insulate angled surfaces up to 60 degrees off of vertical! (see appendix III)

Simplifying the system on a series of prototypes, we eventually arrived at a relatively simple system, using only minor additional hardware and some carpentry work. The edge seal systems remain the same. An additional piece of light casing material is blocked out from the window casement to create a channel. Within this channel, small wheels travel, attached to the spacer tube at the bottom of the curtain. The edges of the curtain are held in place by the edge track. On a small prototype, (4 1/2 x 5 feet), this curtain system has performed reliably on angles up to 45 degrees off of vertical.

We have yet to attempt an actual installation though. Until that time, no thermal performance tests can be conducted and the insulative effectiveness will remain theoretical.

HARDWARE:

Locating or fabricating the hardware associated with an insulating curtain was undertaken at a very early stage. The hardware must be durable, reliable, reasonably priced and able to respond to a variety of window shapes and sizes. Early experiences with spring operated roller shades revealed the difficulties inherent in this system - lack of reliability, inability to function well over large windows and subsequent heavy curtains. IS, which had been using this system, found similar problems and subsequently abandoned the roller shade idea.

Pull cord assemblies, both owner built and commercial, were tested and proved unsatisfactory - the durability and reliability of the system were inadequate.

The hardware which we selected (see Figure 16 and appendix I) has a proven track record gained from years of commercial application. The sprocket assembly is made of heavy duty delrin and operated by a stainless steel bead chain (70 lb. test). Although we have made some minor changes and additions to the hardware, we have been satisfied with the performance of both main components and associated hardware - levelling piece, bead chain connectors and stops, etc.

The plywood curtain end supports which we provide facilitate a range of valence options for the homeowner.

MAJOR CURTAIN HARDWARE COMPONENTS

SPROCKET ASSEMBLY, CURTAIN ROLLER TUBE AND
BEAD CHAIN LOCATED WITHIN WINDOW WELL

FIG. 16

The bead chain allows easy operation of curtains in normally inaccessible locations such as clerestories.

The aluminum tube to which the curtain is attached is two inches in diameter and can span up to 16 feet in length. Longer curtains can be secured to a three inch tube which is easily adapted to the existing hardware.

For those homeowners preferring automatic to manual operation, we supply tubular motors which fit inside the two-inch aluminum tube. Controls can be either timer or temperature activated.

3. COMMERCIALIZATION

As Jeffrey Bryson pointed out in his paper presented at the 1979 Conference on Solar Glazing, "the most efficient automobile engine is still on the drawing board, and will not save one drop of gasoline until driven by the customer. Similiarly, the most efficient window treatment is of no value until it reaches the marketplace."

Of the two options considered for bringing our efficient window treatment to the marketplace - customized vs. owner/builder fabrication - we chose the latter for a number of reasons, including:

i) substantial cost savings for the homeowner - one of the major liabilities facing most commercial curtain distributors is the prohibitive cost of the device. Much of this cost in incurred when large capital outlays for specialized equipment and skills are required for curtain fabrication. By designing an effective curtain with reasonably accessible materials and basic sewing and handyman skills for installation, we have been able to dramatically reduce the cost of the curtain, without sacrificing quality.

ii) increased levels of skills and awareness of homeowners - the recent revival of the owner/builder approach has been noted by a variety of media sources. Magazines, books and an increasing number of products are appealing to this market. Because many of the people with whom we come in contact are keen to pursue this goal of self-sufficiency, or at least responsibility, it is appropriate that the curtain system be available in kit form.

iii) benefits to manufacturer - certain economic advantages are accrued from this approach such as reduced inventory and reduced fabrication equipment. Further, since the business expertise of Sunergy is focused in the small business sector, it

is appropriate that we apply this skill to the insulating curtain project.

Having defined the market orientation, it became essential to determine the skill level and commitment represented by the prospective consumer. A plethora of articles and books abound with do-it-yourself schemes for window insulation systems. Many, however, require a carpentry and/or sewing level of considerable refinement-not to mention some specific, and not always available, tools such as radial arm saws and routers. We decided that an adequate compromise exists between the two extremes of customizing and complete do-it-yourself format. Considerable efforts were directed at simplifying the hardware, the sewing and the instructions. The hardware is durable and the kits contain all materials necessary to fabricate and install a complete curtain - the decorative valence and/or fabric is left to the homeowner's discretion. The tools required to complete the installation are few and common; screw-drivers, hack saw, scissors, drill and bits, sewing machine. The major commitment required of the homeowner is one of time; the five to six hours typical installation time of the first curtain, though, can easily be halved with increasing familiarity with the system.

The assembly instruction are provided in two parts (see Appendix I & II). One large blueprint with a number of detailed sketches provides basic fabrication and

installation instructions. An experience handyman can normally complete installation using this basic instruction sheet. For those less familiar with the curtain, or requiring more details, or have a unique window problem, there is an accompanying booklet to answer anticipated queries. This is presently undergoing expansion.

CONSUMER ASSESSMENT OF PRODUCT:

Having spent much of the fall and winter fielding enquiries concerning our curtain and putting several potential projects on hold due to a lack of curtain fabric; we quickly took advantage of the arrival of the fabric. The first project was in the home of W. Robertson, of Carstairs, where we had earlier installed a curtain made of Tricot (without edge seals). We replaced the Tricot with the ARN with corded edge. The glazed area is 8 ft. high x 7 ft. wide - large enough to conduct in situ testing.

We were contacted in February by G. Powell, in Priddis, concerning our curtain and we responded in March with four sets of curtain hardware and fabric to cover his 400 sq. ft. of greenhouse glazing. A representative from Sunergy was on site during installation of the first curtain but no problems or questions ensued which were not mentioned in the instruction sheet and booklet. The project was delayed somewhat as piping problems mentioned earlier (page 44)had to be resolved.

Having confirmed the reliability of the SunSeal insulating curtain when applied to a typical, then large window area, the next logical situation was more unique. With the advent of superinsulated houses, and their associated thick walls with the windows mounted to the exterior, there have been increasing requests for window insulation systems which operate within the window well recess. Such was the case at the home of B. Moriarty in Calgary. Again, a Sunergy representative accompanied the homeowner as he installed the curtain. Although some additional instruction were needed, and some preliminary minor carpentry work, the SunSeal curtain was fairly easily installed and reliably operated.

All of the above involved retrofit situations, probably the most common application. However, in the case of K. Buchanan of Red Deer, the insulating curtains were anticipated at the design stage and they were accomodated above the window opening. When these curtains are installed, they will be hidden from sight when not in use.

As we undertake more installations, the instructions will be continually refined, as will our skills at installing the curtains in unusual situations.

4. EDUCATION

As any good product, the SunSeal insulating curtain should stand on its own merit. With this in mind, Sunergy has concentrated its efforts in the educational field rather than the strictly promotional. This was also a natural route to follow, given our long experience as educators in the topic of energy efficiency.

Our involvement with workshops and seminars on moveable window insulation follows our increasing interest in this field. We began accumulating information on m.w.i. systems in 1976 and in the fall of 1977, offered a public workshop which included the design of an exterior insulating shutter system. In November 1978, we fabricated and installed an 11 by 5 foot fibrefill quilted curtain in a public workshop at Yamnuska Centre. We rapidly became aware of the problems associated with these moveable insulation devices.

To avoid these problems, we changed our tack to reflective curtain and over the next few years became familiar with commercial products and aluminized fabrics. In January 1981 we conducted a workshop at a client's home near Ma-Me-O Beach, teaching the design, fabrication and installation of reflective insulating curtains. Spring-hinged wooden side valences were used to provide edge seals.

Through this fall and winter of 1981/82, we have continued to provide educational courses on topics of energy efficiency and moveable window insulation. In September 1981, we drafted an information sheet in which we reviewed this topic. The first recipients of this information sheet were participants in a September 17, 1981 meeting of the Solar Energy Society of Canada, Inc., Northern Alberta Chapter. For the meeting, we assembled a one-hour slide show on moveable window insulation, reviewing a variety of techniques and describing the path which we were following to develop the SunSeal curtain. This slide show, albeit having undergone continuous modifications and updating, accompanies the talks which we offer on this subject.

Seminars:

Solar collector workshop, Rocky Mountain House, Sept. 19, 1981
Solar collector workshop, Carstairs, October 24, 1981
Insulating curtain workshop, Jasper, November 14, 1981
Insulating curtain workshop, Carstairs, December 5, 1982
Energy efficiency seminar, Calgary, Feb. 8&9, 1982
SESCI greenhouse workshop, Calgary, Feb. 20, 1982
Alberta Agriculture lecture, Claresholm, Feb. 27, 1982
Central East Alta. Teacher's Association, Edmonton, March 4 &5, 1982
Energy efficiency seminar, March 11, 1982, La Ronge, Saskatchewan
Energy efficiency seminar, Prince Albert, Saskatchewan, March 12, 1982
Calgary HoeExpo display, April 6-11, 1982
Alberta Agriculture Solar Greenhouse Seminar, Wetaskiwin, April 15, 1982

Upcoming events include:
Solar Fair, Edmonton, April 18, 1982
Energy efficiency seminar, May 15, 1982, Calgary
SunDay display, Calgary, May 3, 1982
Energy efficiency construction workshop, Carstairs, July 2-11, 1982

As the number of educational programs which we orrered increased, so too did the number of people interested in our product. To keep these people informed of the development of the SunSeal curtain, we established a postal rapport. These newsletters eventually culminated in the drafting of an information flyer. (see Appendix IV)

5. CONCLUSION

Contemporary energy realities are shaping new understandings. New perspectives in turn promote a wide range of new responses.A typical example in the housing field is the rapid acceptance of design and construction techniques embracing solar, energy efficient objectives. This represents a positive response to a number of strongly felt needs, typically including:

- significant economic benefits through (life cycle) energy savings
- improved home comfort levels
- greater feelings of security, both now and for the future through enhanced independence
- commitment to an enlarged (environmental, global) responsibility
- closer integration with the natural world

Sunergy's activities are strongly motivated by such concerns as these.

Like all R and D projects this work has demanded an extremely multi-faceted inter-disciplinary approach - from the physics of Dupont's labs to the psychology of consumer's living rooms. Criticism and comment has been actively solicited from industry and government scientists, manufacturers, marketing representatives, and most importantly, homeowners. This process, of course, is ongoing.

We are pleased with the accomplishments that have been made. Most of the original criteria set out as goal posts have been realized. The testing work has resolved many important questions and, as to be expected, provoked new questions. This exploration will continue. The greatest endeavour is now to be directed towards field (or living room assessment. We need longer term and a wider spectrum of consumer feedback. The development of a score of prototypes in the shop will never fully be able to anticipate and simulate the living lab of the homeowner. A university student joins Sunergy for the summer for the purpose of expanding SunSeal's track record. This report attempts to highlight some of those areas which an "explorer of the field" would find of greatest interest. It quite

naturally neglects more than it includes. The process of preparing a report does not in any way suggest the termination of a process but rather an interlude in the dynamics.

The concept of sealing in the warmth of the sun is appealing in its apparent simplicity.However, like the curtain's namesake, the accomplishments are there, but are at times elusive. Objectives and their related problems are often slippery. The waters at times may have been rough - but SunSeal emerges a buoyant reality!

Save your dollars, save your heat,

Buy insurance that inflation can't beat

Stand up as an ecological participant

And help curb the acid precipitant

Gain self-reliance without defiance

Grow winter greens within your means

All this? - you ask

That's quite a task

But with the sun

It can be done

And insulation for walls and roofs

Combining details for air/vapour proof

And to keep your windows a thermal deal

No better friend you'll find than our - SunSeal

- Anonymous writings found scrawled inside a Clivus at Sunseed

REFERENCES

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4. William Langdon, Moveable Insulation, 1981
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6. Passive Solar Heating and Cooling Conference Proceedings, 1976
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9 Proceedings of the 5th National Passive Solar Conference, 1980
10. R. D. Quiroutette, "Insulating Window Shutters", Building Practice Note, Division of Building Research, National Research Council, Ottawa, June 1980
11. "Solar and Long Wavelength Energy Transmission of Materials," by Godbey et. al. for the American Society of Agricultural Engineers, June 1977.
12. William Shurcliff, Thermal Shutters and Shades, 1981
13. Solar Glazing: Topic Conference June, 1979
14. "Thermal Performance of Frame Walls" by G. O. Handegord, N.B. Hutcheon, ASHVE Transactions, vol. 58, 1952
15. Use Solar Daylight and Heat PPG Industries booklet prepared for participants in the Passive Solar Conference, 1978

Appendix I

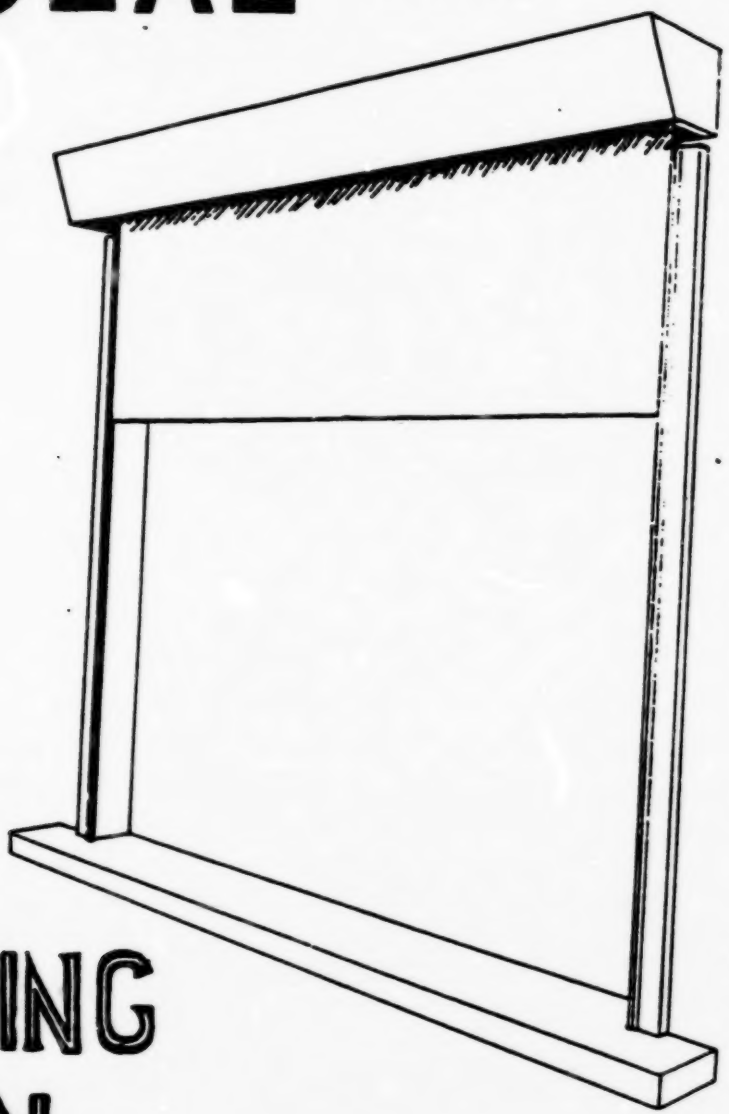
Appendix I is not included in this re-production of the SunSeal report as it is a large fold-out that cannot be reduced. This fold-out illustrates the select hardware components of the Moveable Insulating Curtain and can be obtained by contacting the proponent directly at:

SUNERGY SYSTEMS LTD.
R. R. #2, Carstairs, Alberta
335-4960/335-4988

SUNSEAL

APPENDIX II

Draft Version



INSULATING CURTAIN

ADDITIONAL NOTES FOR SUNSEAL INSULATING CURTAIN

INTRODUCTION: This manual is intended as a clarification and addition to the instruction sheet. If the instruction sheet leaves you unclear or should problems arise, or just to be sure, consult this booklet.

As well, this manual attempts to explain why all of the steps in the instruction sheet are vital - and how they affect the performance of the curtain. To understand this, it is useful to understand the basics of insulating curtains.

THEORY: For the insulating curtain to perform, dead air spaces between the reflective surfaces must be created. Hence, the TWO-layer curtain. The air space between the layers is maintained by a polyester spacer strip (see S on instruction sheet) at the top, and a pvc tube (see F) at bottom.

Sealing the air spaces will reduce heat loss and condensation problems. The bottom seal is created by allowing the fully-extended curtain to rest on a level sill or floor. To stop air movement around the top, a loop of weighted plastic rests upon the curtain as illustrated in Step 11. Edge seals are created by sewing piping into the vertical edges of the curtain. This piping runs in a slotted tubular track (H) as the curtain is raised or lowered and effectively deters air movement around the curtain edges.

PRACTICAL: STEP 1 is quite self-explaratory. The sewing tasks are not difficult but care must be taken to ensure that the curtain is of uniform width. Also, the piping should be sewn straight, flat and parallel to ensure a reliable feeding into the pvc edge seal track.

STEP 2: It is useful to drill small pilot holes in the plywood curtain supports - be careful not to drill entirely through the wood.

The diagram shows left hand operation of the curtain. Reverse the pieces for right hand operation.

STEP 3: A) While being cut, the tube edges will be made rough. Remove the burrs with a metal file or utility knife.

B) In the central diagram, the left hand side shows an exploded view of the various pieces. The right hand side indicates how the tubes and end cap fit together.

STEP 4: Typically, the curtain supports are mounted as close to the top of the window as possible. To locate solid backing, you can tap a long finishing nail through the wall finish until you strike solid wood. If you are unable to locate solid backing behind gyproc, you may use gyproc fasteners - keep front and top valences accordingly lightweight.

STEP 5: If there is tension, either increase the distance between the curtain supports or loosen the lock nut (B) on the sprocket assembly.

If there is a "strange" noise, i.e. grinding or jamming, check to see that the curtain supports are plumb and perpendicular to the wall. Make necessary adjustments. If the lock nut is too loose, this can also

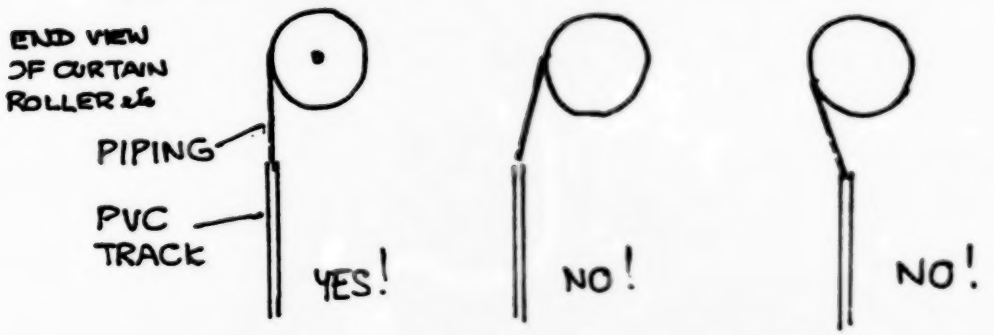
create "strange" noises.

STEP 10: EDGE SEALS

This step is crucial to the effectiveness of the curtain in prvent-ing air leakages and thus reducing heat loss and condensation problems. There are several small but important steps to follow to ensure a reliable and effective edge seal.

A) The slotted pvc edge track should be cut as long as feasible. The intent is to ensure that at least two inches of the piping remain in the pvc track when the curtain is fully raised. This encourages the piping to feed smoothly into the track when the curtain is sub-sequently lowered. The cut edge of the track should be thoroughly sanded, filed or scraped smooth with a utility knife. This will deter the piping from catching on a rough edge.

B) The edge track should be secured to the wall in such a way as to allow the piping to feed DIRECTLY into the track as illustrated below. If necessary, you may block the track out further from the wall using the extra double-backed foam tape or by increasing the thickness of your window casing.



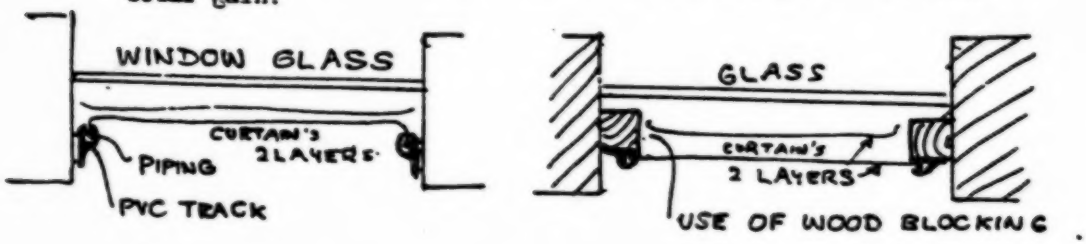
C) Any sideways tension on the curtain will deter the piping from feeding into the track smoothly. Allow enough play to avoid this.

Make sure the piping feeds straight down into the track.

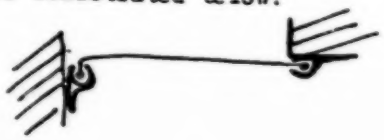
ADDITIONAL OPTIONS

As with all instructions, these are meant to apply to a typical window in a typical home with typical window casings, sills and decor. However, although some modifications must be made, the systems apply to almost all vertical windows typical or not. To give some examples:

EX. 1: The curtain is to be mounted WITHIN the window well. Because the edge track can be mounted sideways as illustrated, accommodating this request is not a problem. Do not forget, though, that the curtain, tube, hardware, and valence will take up additional space within the window opening and will reduce solar gain.



EX.2: The window casing is on one side of the window only. The other is, for instance, in a corner, faced with gyproc. Again, the edge seal track can be mounted sideways on one side, while the other can be mounted typically, as illustrated below.



EX. 3: Angled glazing. With some additional hardware and instructions, the system can be adapted to respond to angled glazing.

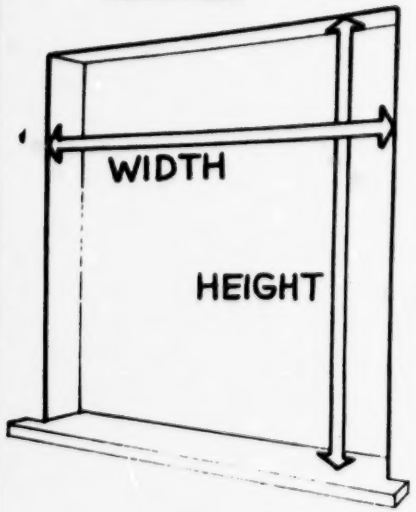
This instruction booklet and diagrams are in a continual state of updating, adapting, evolving. If you have any particular problem or situation, do not hesitate to contact Sunergy. Any feedback as to their clarity, effectiveness, omissions, etc. will be greatly appreciated.

Sunergy Systems, Ltd.,
R.R.#2 Carstairs, Alta.
TOM 0N0
335-4960
-4988

One of the many angled prototypes
(Motorized for Testing)

Job Application

ORDER FORM



Width = _____inches

Height* (from top of window to sill or floor) = _____inches

SunSeal insulating curtain kit comes complete with fabric and all hardware required to install curtain. It is left to the homeowner to provide decorative fabric and valence material if desired.

Name: _____

Address: _____

_____

Telephone: Home _____

Bus. _____

Approximate cost is:

Window area (sq.ft.) x $4.00=_____

Please enclose a cheque or money order for half of this amount.

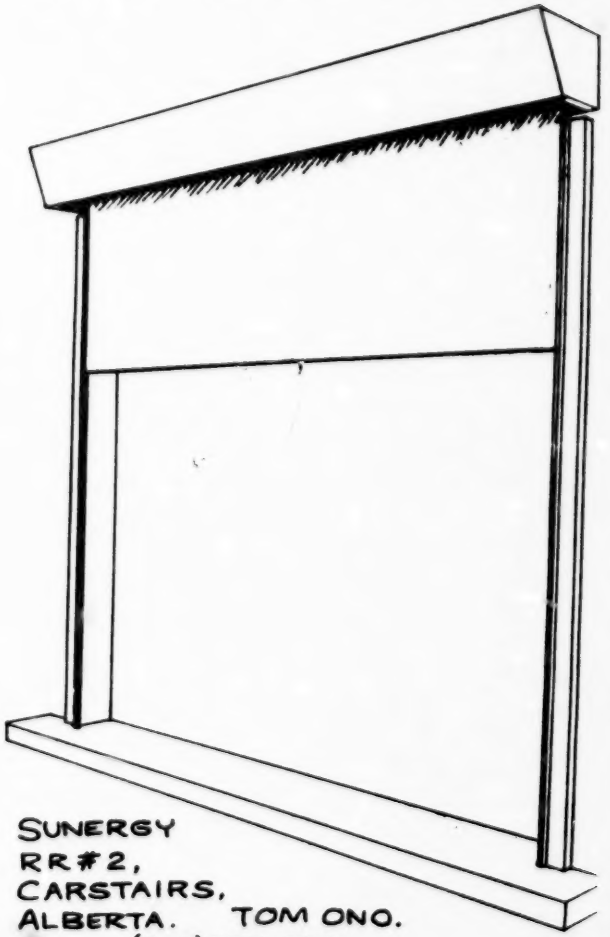
---

*In some cases you may wish the curtain bottom to rest on the floor rather than on a window sill. If so you should measure the curtain height from the floor to the top of the window opening

SUNERGY SYSTEMS LTD.
R.R.#2
CARSTAIRS, ALBERTA
TOM ONO

SUNSEAL

INSULATING CURTAIN



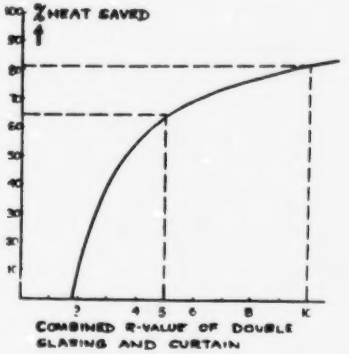
SUNERGY
RR#2,
CARSTAIRS,
ALBERTA. TOM ONO.
Phone : (403)335 4960

No one wants to live in dark, dingy caves. That's why windows were invented. They provide for natural daylighting and viewing. Designed properly, they allow sunshine to help heat the home. And of course plants like the sun too. Windows help meet all these needs. BUT they are poor insulators. Windows represent the single most important source of heat loss of a well insulated home.

AND KEEP IT IN!

To conserve this heat, window insulation is essential. But how much?

SunSeal insulating curtain, used in combination with double glazing, gives an R-value of about 5. From the graph you can see that this cuts night time heat loss by about 2/3. Doubling to R-10 dramatically increases the cost, complexity and inconvenience of the insulating device–but reduces further heat loss only slightly.

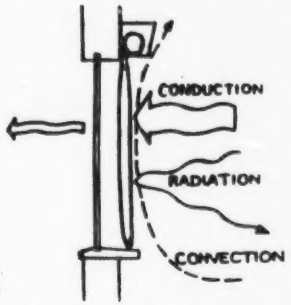


HOW?

Cover your window with a sleeping bag?

Maybe some exterior shutters would help–until it snows!

SunSeal insulating curtains are compact, interior and easy to operate. They reduce heat loss three ways:



- radiant heat is held in by two layers of highly reflective, low emittance aluminized fabric.
- conductive heat loss is reduced by the creation of two dead air spaces.
- convective heat loss is stopped by effective top, bottom and side seals.

Effective Insulation

- R5 in combination with double glazing reduces night time heat loss by two-thirds
- rejects unwanted summer sun
- curtain consists of two layers of aluminized rip-stop nylon

Easy Operation

- manually operated with bead chain
- automatic option with electric motor and controls

Aesthetics

- either bronze or white fabric faces interior
- curtain is hidden in valence above window when not in use
- removable decorative fabric can be easily attached
- wipes clean with damp cloth

Inexpensive Kit Form

- detailed instructions accompany purchase of kit
- installation and fabrication require very basic sewing and carpentry skills
- typical cost is $4.00 per sq. ft. FOB Carstairs, Alta

Reliability

- durable fabric resistant to sunlight
- heavy duty molded plastic hardware
- 70 lb. test stainless steel bead chain
- insulating test results available upon request

Applicability

- to large and small window areas
- to retrofit situations
- to within window well, as well as in valence above window
- to angled glazing (with some additional hardware)

National Research Council Canada
Conseil national de recherches Canada

Division of Building Research
Prairie Regional Station

Division des recherches en bâtiment
Agence régionale des Prairies

APPENDIX V

April 7, 1982

Mr. Bernie Lawrence
Sunergy Systems Ltd.
R.R. #2
Carstairs, Alberta
T0M 0N0

Dear Mr. Lawrence,

We have received your letter regarding our oral comments on your system for window testing. My comments were related to the use of the heat flow meter and the question of possible errors. Ideally the heat flow meter should not interfere with the transmission of heat. In all cases it does have some effect but the effect should be minimized. When the heat flow meter is on the glass it will intercept any radiation that would otherwise pass through the window. In addition to that, even though the thermal resistance of the heat flow meter is small, it is significant when compared to the very small resistance of the glass. As a result it will tend to act as insulation thus reducing heat flow through itself and giving an output that is too low.

I am not sure just what discussion we had about thermocouples but if the temperature drop across the insulation was measured, that temperature difference coupled with a thermal resistance for the insulation would give a measure of heat flow. Of course it would not tell you about edge effect which is often very important in that kind of system.

I hope these are the subjects that you wanted me to touch on. Please feel free to contact us again if we can be of help.

Yours very truly,

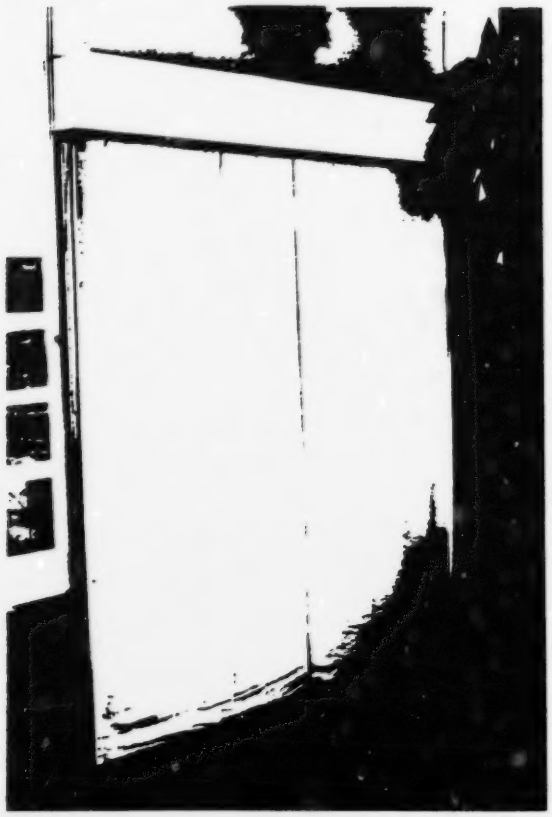
C.P. Hedlin,
Officer-in-charge

82-74

Saskatoon, Saskatchewan
S7N 0W9

MODIFIED FREEZER ARRANGEMENT

SHOWING TEMPERATURE TRANSDUCERS AND HEAT FLUX METER



TYPICAL INSTALLATION SHOWING VALENCE AND DECORATIVE FABRIC

INSTALLATION WITHIN WINDOW WELL

POOR

QUALITY

ORIGINAL